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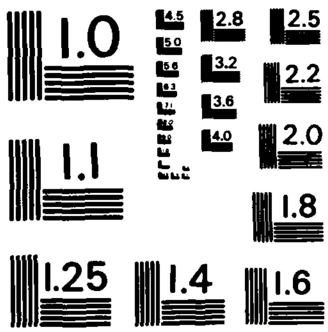
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AN ANALYSIS OF COMPUTER MODELING
PARAMETERS FOR USAF
CONUS CARGO MOVEMENT STRATEGY

THESIS

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AN ANALYSIS OF COMPUTER MODELING PARAMETERS FOR USAF CONUS CARGO MOVEMENT STRATEGY

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

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Preface

This study lays the groundwork for any future efforts to model USAF CONUS freight movements. We became involved in the study after HQ USAF/LET directed HQ AFLC/DST to organize a CONUS Cargo Movement Study (CCMS) group. This group was tasked to collect information on all CONUS freight shipments, and also determine if modeling the system was feasible. Since that tasking involved many separate actions, we agreed to analyze several of the subareas of the overall effort.

The thesis is organized into chapters based upon the the subareas we analyzed. Therefore, although each chapter is virtually a separate entity with its own background, methodology, and findings, all chapters relate to the overall CCMS project. Some of the research is designed to describe the nature of Air Force CONUS cargo movement requirements, and will be used to corroborate findings of independent research accomplished by HQ AFLC/DST. The reaminder of our research is designed to establish computer modeling parameters and decision criteria for the CONUS cargo movement system.

We would like to thank the leader of the CCMS study group, Mr Andrew Figueroa, and his assistant, Capt William Watchorn for their assitance, especially in helping us understand the intricacies of the USAF transportation world.

Also, Mr Fred Rexroad, HQ AFLC/XRS, and Mr Ire Saxton, HQ AFLC/LMTS, provided invaluable technical assistance in the area of computer programming and use. Our final acknowledgement goes to our advisor, Lt Col Richard E. Clarke, for his guidance, but then, if it had not been for him, we would not have been involved in this study at all.

Hugh H. Garrett | Craig K. MacPherson

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Abstract

This analysis provides a foundation upon which to build a model of the Air Force CONUS freight shipment network. The general findings were that a model is possible, but attention must be given to that data which is collected for input to the model; that some of the simplifying assumptions about shipping costs would induce significant error into a final model; LOGAIR costs compete favorably with common carrier charges for similar service response; and virtually no model is commercially available that could be easily adapted for use in modelling this system.

The data collected by HQ AFLC is not complete when compared to the independent T-WRAPS report. The categories of variables adequately describe each shipment, although the usefulness of the inputs would improve with detailed hazardous material coding and distance to be shipped. Collection of CONUS cargo movement data should be integrated with standardized shipment documentation and reporting procedures for all Air Force cargo.

This study used the accumulated data base to view the specific frequency distributions for weight, volume, number of pieces in a shipment, and priority for three separate populations: all shipments, Transportation Priority 1 shipments, and Mission Capable (MICAP) shipments.

The study analyzed cost behavior. Specifically, any future model should not assume cost for a mode expressed in dollars/pound to be linear for weights under 100 pounds. Also, any future model should not assume cost of shipping to be independent of the distance to be shipped.

Transportation strategy requires accurate information on transportation costs. This study computed LOGAIR costs in cents per pound based on all LOGAIR cargo moved, actual air eligible LOGAIR cargo moved, and only actual air priority LOGAIR cargo. Compared with published common carrier rates, LOGAIR costs based on all LOGAIR cargo moved were cost competitive for similar service available during the study.

AN ANALYSIS OF COMPUTER MODELING PARAMETERS FOR USAF CONUS CARGO MOVEMENT STRATEGY

I. Statement of the Problem

General Issue

Air Force traffic managers have diverse cargo movement requirements, stemming from the variability in shipment size, weight, and special handling requirements, as well as differences in delivery date requirements. To meet these different cargo movement demands, three general alternative courses of action are possible. First, the Air Force could rely completely on dedicated transportation service. Dedicated transportation service would be completely at the disposal of the Air Force and only used by Air Force shippers. Military commitments limit the availability of organic airlift provided by USAF active-duty, Reserve, and Guard units (47). Therefore, dedicated air transportation service requirements are met by contracting with common air carriers. United States Air Force Logistic Airlift (LOGAIR) is an example of dedicated contract service. This service is defined as follows:

> LOGAIR is a scheduled logistics air transportation system operated in support of first-line weapons systems over established CONUS routes by commercial carriers under contract and operational control of the Air Force Logistics Command (35).

The second general alternative is for the Air Force to use nondedicated transportation service as demands dictate. Nondedicated transportation services are provided by common carriers, and therefore, are not solely at the disposal of the Air Force. United Parcel Service, the US Postal Service, Federal Express, commercial truck companies, and freight forwarders are examples of nondedicated common services. The third option involves a combination of the two.

Dedicated service is the most responsive and flexible, and can address critical requirements with the most ease. However, the extra responsiveness and flexibility comes at a price. The Air Force pays the total variable and allocated fixed costs of dedicated service. Conversely, nondedicated service is more cost effective because the Air Force is sharing operating costs with other users. As a trade-off, the Air Force loses control over routing and line-haul pick-up and delivery points. Also, most air freight carriers and air freight forwarders have cargo weight limits. Therefore, any very heavy or very large shipments would have to go by train or truck, and would not be able to meet a short deadline.

The importance of wartime readiness directly impacts the value of dedicated service. For example, the excess capacity in LOGAIR is routinely used for shipments not requiring dedicated service, but this capacity allows LOGAIR to quickly respond to a wartime surge in the requirement for dedicated service. Therefore, the costs of LOGAIR must take into consideration the value of wartime readiness for the defense transportation system.

Weighing the advantages and disadvantages of dedicated service and nondedicated service, the optimum strategy appears to be a combination of the two. Dedicated services must be established for shipments that cannot be supported by nondedicated services. The choice of commercial air, rail, or truck carriers to provide the nondedicated service is normally based on minimizing shipment costs within established delivery time constraints. Maximum use of the competitive nondedicated services would be expected to keep the transportation budget at the lowest possible level.

Recent Congressional interest in the DOD and Air Force budgets has required the Secretary of the Air Force to be able to justify the money requested for transportation of Air Force cargo. At least three questions must be answered to accurately formulate the transportation budget.

1. What does the Air Force expect to ship annually?

2. Of those expected shipments, what quantity cannot be adequately serviced by nondedicated common carriers?

3. Given this requirement for a certain level of dedicated contract service, what quantity of the forecast shipments adequately serviced by common carriers can be shipped more cost efficiently on any excess capacity in the dedicated contract service?

Therefore, preparing the budget for the Congressional enactment process requires forecasting all USAF CONUS cargo movements and classifying these demands into transportation mode categories, dependent on priority, size, weight, and special handling requirements. The decision for contracting dedicated transportation services must be based on common carrier capability to adequately service these transportation requirements, tempered by the importance associated with convenient, reliable, and quickly expandable service versus the most cost efficient service. The overall transportation budget request combines the funds for contracting the desired dedicated transportation services and the funds necessary to procure common carrier services for the remaining transportation requirements.

Specific Problem

Three specific problems stem from the general issue.

1. The Air Force needs an empirical data base to forecast point-to-point annual transportation requirements for all CONUS origin-destination pairs. Without a consolidated data base, the Air Force cannot analytically determine what must be shipped on dedicated transportation.

2. The Air Force needs decision support tools available to help transportation managers determine the quantity of shipments that may be cost efficiently moved by the excess capacity of dedicated contract service, even though the shipments do not require dedicated contract service.

3. The Air Force needs empirical decision support tools available to help transportation managers determine the minimum overall transportation costs given forecast transportation requirements and the transportation system's dedicated contract service level.

To address these three issues, HQ USAF/LE recently tasked HQ AFLC to prepare a CONUS cargo movement analysis study plan; a plan which would outline the approach to solving the problems raised in the general issue. HQ AFLC proposed a two-phased approach for the study. The first phase involves developing and analyzing an empirical data base of CONUS cargo shipments in order to identify actual CONUS cargo movement requirements and provide the basis for assessing the effectiveness and efficiency of CONUS cargo movement. This phase requires two steps:

1. Collecting, validating, and aggregating the data to provide both summary statistics and specific statistics for each traffic channel.

2. Describing the data base by determining the distribution of important variables and analyzing any significant interrelationships. (For example, does weight vary proportionally with size?)

The second phase involves writing a plan for the development of a computer-based model to assist the decision-maker in the design and analysis of alternative strategies for the movement of cargo within the CONUS, addressing specific problem areas two and three.

Four areas from the overall study plan are covered in this thesis. The first area is an evaluation of the empirical data that HQ AFLC is collecting. The combination of manual and automated data collection methods for over 15 million data elements warrants evaluation of the reliability, validity and practicality of the data. The second area is a statistical analysis of the aggregate data. The information from this study not only describes the characteristics of Air Force CONUS cargo shipments, but can provide the inputs for a model-based decision support system. The third area evaluates cost behavior for several transportation modes to aid in model development. Finally, the thesis compares these costs and LOGAIR Tariffs to the actual costs of LOGAIR service.

Background

In April 1983, the office of the Secretary of the Air Force requested that consideration be given to tailoring LOGAIR to the growing pool of excess Boeing 727 freighters in the United States resulting from changes in the domestic air cargo industry. This concept's development was based on the belief that LOGAIR service could be upgraded, cost of service reduced, and Civil Reserve Air Fleet capability improved with the use of Boeing 727s in a "Hub-Spoke" LOGAIR network. Studies by HQ AFLC/DSXMP and the Air Cargo Management Group of Bellevue WA indicated that a single hub system would not be cost effective without introducing large, high capacity aircraft into the system (45). According to the Air Cargo Management Group, the most cost effective alternative would be to use Kelly AFB as the single hub with both spoke and petal routes, and Boeing 747s to move cargo between the Air Logistics Centers and the Aerial Ports of Embarkation. Further studies within HQ AFLC/DS indicated transportation system improvements could be most quickly realized in the area of new and advance cargo processing procedures, rather than in improved route structures (45:Executive Summary).

In September 1984, HQ USAF tasked HQ AFLC to develop a proposal for a "Hub-Spoke" LOGAIR system. In developing their proposal, HQ AFLC raised questions about quality of data used in the two studies mentioned previously. These studies only addressed the amount of cargo moved on LOGAIR. For the LOGAIR requirements to be seen in proper perspective, all demands for the movement of Air Force cargo within the CONUS should be addressed. This realization prompted HQ AFLC to initiate a CONUS cargo movement analysis of the overall Air Force transportation system with the joint goals of identifying all CONUS cargo shipments and recommending a plan for developing a computer-based model of the CONUS movement system. The model's purpose would be to help determine a CONUS cargo movement strategy which would most effectively and efficiently meet the transportation requirements of Air Force shippers.

Additional research on the LOGAIR system has produced recommendations for developing the LOGAIR route structure and determining the optimum LOGAIR schedules. However, none of the studies attempted to analyze LOGAIR based on all CONUS cargo movement, but rather on LOGAIR cargo movement only. If the assumptions about the data base incorporated into the research should prove invalid, then the conclusions drawn from using that data base would likewise be invalid.

McPherson and O'Hara (29:52), in writing a computer program to determine LOGAIR schedules, assumed that daily demand was a constant 1/365 of the annual total. Moberly and Gorychka (30:23) attempted to develop a model for LOGAIR schedules without any assumptions about the daily demand for

LOGAIR. The intent was to allow the model to be useful under various, differing circumstances. However, by their own admission the model could only be flexible for changing yearly demands, and not the daily variability over the period of one year. Data used in weighing the objective function was based upon yearly forecasts that do not reflect the degree of variability in daily cargo flows. Similarly, cost and priority would be expected to fluctuate, because they are a function of cargo flow. Consequently, the model is limited in ability to account for these variations (30:48).

Boudreaux and Olansen used forecasts provided by each major Air Force installation. A second source of data was past shipments, because HQ AFLC/LOTSL assumed "past demand was accurate for future planning (5:4)." Neither assumption was verified in the report, nor were references cited to validate the claims that:

1. Air Force installations accurately forecast future cargo movement requirements.

2. Past shipments are indeed an accurate indication of future demand for the transportation system.

If either assumption is not valid, then Boudreaux and Olansen's conclusions about LOGAIR are suspect.

Van Valkenburgh (44:25-28) proposed a single hub concept for LOGAIR, independent of the studies referenced above. However, he assumed the daily shipments in and out of a station equaled 1/365 of the annual total; an assumption found in the previous studies. Again, this assumption was not validated. If demand varied seasonally or even within a given week, the savings proposed from this research would be inaccurate.

Payne and Scott (36:44) furthered the initial work of Van Valkenburgh, however they also assumed that daily tonnage was equal to 1/365 of demand. The authors developed a statistical distribution of the entire system by drawing a random sample. However, this distribution was only for the entire system and research was not conducted to determine if individual traffic channels conformed to the distribution of the population.

The numerous LOGAIR studies were dependent on limited CONUS cargo shipment information. As of September 1984, AFLC did not have the empirical data base of all CONUS cargo shipments needed for analysis. In an effort to begin to validate the assumptions about CONUS cargo shipments, HQ AFLC initiated a data collection effort. Developing a data base under current reporting procedures required a massive effort on the part of Air Force transportation personnel. Therefore, HQ AFLC decided to limit the data collection effort to a six month period beginning 1 October 1984 to minimize the additional workload required for those bases that would have to manually report.

The CONUS cargo movement analysis study plan conducted by HQ AFLC also addressed the need to assist the decision-maker in the design and analysis of alternatives strategies for the movement of cargo within the CONUS. The key to transportation strategy is understanding the trade-off between performance and cost. According to Magnanti and Wong, "Any design of a transportation system will usually provide substantial excess capacity during most of the system's operations" (27:6). To have a transportation system that is both effective and efficient requires a balance between the performance or capability that management deems necessary and an acceptable level of excess capacity generated during non-peak demand on the system. Any attempts to improve efficiency by minimizing costs will always be constrained by the system's effectiveness in meeting management's performance requirements.

Crainic, Fernand, and Rousseau stated that "the goal is the generation of economically sound global operating strategies ensuring a good level of service in terms of delays and reliability" (6:165). Success in the market place for commercial transportation systems is a function of competitive performance and price. Historically, USAF transportation management has focused on the performance necessary to meet the Uniform Material Movement and Issue Priority System standards, with the costs of excess capacity a secondary consideration. The emphasis on performance, without the balancing economic constraints typical in commercial transportation systems, is based on general acceptance of excess capacity as wartime surge capacity and the view that the peacetime use of excess capacity for low priority shipments is an efficient allocation of transportation resources.

Consequently, the recently increasing pressure on the DOD budget has led to questions about the efficiency of the USAF transportation system for peacetime operations.

Attempts to answer these questions have led to much research effort towards quantifying transportation performance and costs to provide a basis for decision-making. Anthony divides these decision-making activities into three levels--strategic planning, tactical planning (management control), and operational control (2:15-18). The transportation manager's decisions involving transportation planning and control tend to revolve around the design of transportation networks based on transportation performance and costs. "Network design issues pervade the full hierarchy of strategic, tactical, and operational decision-making situations that arise in transportation" (27:1). Assad further reduces network design into network synthesis problems and network analysis problems, where network synthesis concerns the generation of the network configuration, while in network analysis a specified network configuration is analyzed with respect to some objective function (3:38).

Strategic planning tends to focus on either acquisition of transportation capability or the determination of transportation performance requirements, and generally involves decisions with impacts more than a year away. Tactical planning network decisions are concerned with the effective use of the transportation resources available, with a time horizon of a few months up to a year (27:2-4). At the bottom of the management hierarchy, operational control should strive to efficiently use the transportation system resulting from strategic and tactical planning, with decisions having an immediate impact. Therefore, if transportation managers at all three levels of management are provided with decision support tools that adequately aid the decision-maker in planning and controlling the transportation system, then the result should be an effective and efficient transportation system.

Elam and Schneider contend that management involves the functions of establishing goals, defining constraints and policies, and developing plans. Obviously, the goals for the three management levels are interrelated, and likewise for constraints and policies, and for plans. Not so obvious is the fact that "constraints and policies at one level tend to become goals at the next lower level, and plans at one level become constraints and policies at the next lower level" (11:5). Elam and Schneider also discussed the appropriateness of optimization models for the different management levels.

Decisions at the strategic planning level tend to be subjective and qualitative, thus the application of mathematical formulations for optimization models to support decision-making is limited (11:5). A clear example of this limitation is the failure of HQ AFLC to establish a quantitative description of the "best" level of LOGAIR service.

The need for a limited amount of LOGAIR service for certain types of cargo can be easily justified, quantified, and cost evaluated, but the "numerous nonfinancial advantages of LOGAIR such as routing flexibility and control, schedule reliability, and availability for emergency operations" (10:6) require the manager's subjective judgment of value. Until strategic planning level management determines the level of LOGAIR service desired, tactical planning and operational control management decisions are limited.

Once transportation resources are committed, then management at the tactical planning level attempts to manage these quantifiable resources by establishing goals, defining constraints and policies, and developing plans. "Thus the use of optimization models at this level can be viewed as a vehicle through which managers can evaluate different constraints and policies in terms of multiple objectives that are consistent with the overall structure provided by the strategic planning level" (11:6). An example of tactical planning decisions are the development of LOGAIR route structure and schedules.

At the operational control level, the management decision is limited to completing tasks within the environment created by the strategic planning and tactical planning management levels (11:6). The task and decision alternatives are generally clear and lend themselves to a decision support tool based on an optimization model. An example of operational control level decisions is a traffic manager's day-to-day mode and carrier selection for shipments, based on minimizing costs within programmed constraints, such as vehicle capacity, and size, weight, and special handling requirements.

Examples of current decision support applications for the three management levels are pertinent to the second phase of the study plan. This review addresses decision support tools used by a commercial shipper, two commercial transportation companies, a government transportation agency, and AFLC. Sears Roebuck and Company was the only commercial shipper considered large enough for meaningful comparison with DOD. Commercial transportation companies selected were CSX Corporation, primarily due to its multi-modal capability (rail, truck, barge, and pipeline), and Leaseway Transportation, due to its record as an innovator in computer-based decision support tools for transportation problems. Finally, the shipment routing decisions made by the Military Traffic Management Command (MTMC) seemed anal-agous to those faced by the Air Logistics Centers (ALC) of AFLC.

Decision support tools typically associated with the strategic planning level include models for the location and numbers of warehouses and other facilities. Although computer software is readily available for these applications, for example Leaseway has two models called DISPLAN and WARELOCO (32), decisions regarding where to locate DOD supply points and demand points are not under review. As Elam and Schneider suggested, optimization models have limited application at this level. Similar to HQ AFLC's "best" level of LOGAIR service decision was Sears' strategic decision to abandon organic transportation service, except at the local level, in favor of common carriers (46). With the deregulation of the transportation industry, a company the size of Sears can now enjoy the negotiated common carrier rates that were always available to DOD. Likewise, since MTMC relies principally on commercial transportation services, strategic planning for peacetime operations is limited (25).

As expected at the tactical planning level, there are many applications of decision support tools in the commercial and government sectors. Leaseway has TNET, which determines optimum linkages between supply and demand nodes, and CNET, which identifies consolidation points to improve transportation utilization (32). In addition to the studies of LOGAIR routing and scheduling discussed in the previous section on data base assumptions, three recent optimization modeling attempts for LOGAIR routing, scheduling, and cargo allocation are considered.

Two of the studies developed at Southern Methodist University and sponsored by the Air Force Office of Scientific Research provide the optimization models currently used by HQ AFLC/DST to aid development of LOGAIR route structure and aircraft schedules (1 and 24). Based on mathematical programming, network theory, and distribution statistics, a complementary pair of multicommodity network flow models is used to design the air cargo network and shipment plan, with the objective of selecting the least cost set of cargo routes which satisfy the point-to-point demands for cargo movement among LOGAIR stations (24:3,7). This is known as the D065 LOGAIR modeling system.

Nygard and Downes presented a preliminary proposal in July, 1984 for computer-based optimization algorithms for LOGAIR cargo allocation and routing. Currently, carrier capacity is allocated to the LOGAIR stations for each route by HQ AFLC LOC/XOLG based on cargo requirements messages over the LOGAIR communication network. The proposal suggests development of an online computer-based system to prepare cargo allocations using a mathematical optimization algorithm called ALLOCATE. The second algorithm called SELECT recommends a flexible route structure limited to a fixed set of alternatives as the most efficient route structure, using a variation of the vehicle routing problem as an extention of ALLOCATE (33). Both computer-based optimization algorithms were approved, with contracts for delivery of the model in January 1986.

At the operational control level, the traffic manager's decisions mainly involve the day-to-day mode and carrier selection for cargo shipments. Deregulation of the transportation industry in the last decade led to the proliferation of transportation tariff rates, making manual selection of the optimal mode and carrier by the traffic manager very difficult. Computerized transportation information systems are now virtually required for the traffic manager's decision-making (19:95).

The computer software industry continues to expand to meet the need in the commercial sector by providing tariff rate data bases to aid the decision-making process, and the relative low costs for micro-computers provides the access capability. Research by Hauser and Chesley indicates that for transportation offices that handle more than 200 shipments monthly, the decision support offered by micro-computers and tariff rate data bases is cost effective (19:100). The virtual universal availability of micro-computers within DOD limits the real expense to developing and maintaining the tariff data base.

With this online, interactive system, the traffic manager has decision support for selecting the lowest cost mode and carrier and for maintaining a record of freight in terminal for shipment consolidation decisions. This system could also provide reliable shipment documentation and reporting to a data base that supports strategic and tactical planning level decision-making.

Finally, Hauser and Chesley suggest that for transportation offices that handle less than 200 shipments monthly, the computerized transportation information system can generate hard-copy routing guides to aid the decision-maker

(19:101). Sears provides decision support for its traffic managers using this method.

At Sears national headquarters, transportation managers have developed a computer-based decision support tool in conjunction with Distribution Sciences, Inc. Inputs of origin-destination and description of the goods for shipment, yields the shipment routing and costs. The transportation manager can also evaluate weight break points to establish consolidation protocol. Rather than providing online capability at all warehouses, Sears develops routing guides for each location and revises these regularly to maintain current tariff rates (28). Due to reasonably standardized warehouse-to-retail store routings, and the rather limited number of modes to be evaluated due to homogeneous time constraints, this system works well for Sears.

CSX has a management information system (MIS) that presents the tariff rates for all the available company services. The CSX sales representative evaluates a customer's transportation requirements, considers the services and rates available via the MIS, and then selects the "best" method for shipment (9).

Decisions for all shipment routing in MTMC are made at two area commands. The computerized decision support is limited to selection of the lowest cost carrier for a given mode. The mode selection is made by the traffic manager based on the shipper's request (25).

Until recently, the decision support tool provided for the ALC traffic managers by HQ AFLC/DST was similar to that of Sears. A Transportation Automated Routing System (TARS) guide was custom-designed and regularly updated for each ALC. Due to the large number of shipments from ALCs and the heterogeneity of shipment services required, consolidation of tariff rates was necessary, but the TARS guides still provided limited decision support at best. Consequently, AFLC has developed a decision support tool called Mode Carrier Selection (MCS) to aid the traffic manager. MCS is a computer-based system using a mathematical optimization algorithm to determine the mode and carrier. The data base of mode and carrier tariff rates is updated monthly. A prototype has been successfully implemented at Warner-Robins ALC, and the system is scheduled to be online for all ALCs by December 1985 (39).

In conclusion, the plan for the development of a computer-based model to assist the decision-maker in the design and analysis of alternative strategies for the movement of cargo within the CONUS should take into consideration all the management levels involved in transportation decision-making. The appropriateness of various modeling techniques for the three levels must be considered for any proposed development of a transportation model.

Research Objectives

The overall CONUS Cargo Movement Analysis effort identified in the General Issue, Specific Problem and Background sections is multi-faceted. This the .s has selected several of these facets to address. In some cases the research will be corroborating independent work of HQ AFLC/DST, and in other cases the research will be a unique effort. Although the specific objectives selected are somewhat independent of the others, each is integral to the composite effort.

With that premise in mind, this thesis has four separate objectives, each relating to a separate phase:

1. Determine the reliability, validity, and practicality of the empirical data base collected by HQ AFLC/DST.

2. Determine the nature of USAF CONUS freight shipments by summarizing the appropriate statistics, analyzing the relative and cumulative frequency distributions, and determining the empirical relationships between key variables.

3. Determine the linearity of transportation costs for weight vs price for common carrier modes of transportation; first assuming distance to be fixed, and then assuming distance not to be a factor.

4. Compute actual LOGAIR costs for specific channels and compare those costs to the LOGAIR Tariffs charged DOD shippers, and to the costs for similar service provided by common carrier transportation companies.

Each research objective is expanded in a separate chapter that contains the objective, methodology and findings. The research objectives of the thesis address only a peacetime cargo movement system. However, Air Force planners have defined ratio relationships between peacetime and wartime flying hours that can be factored into commodity oriented traffic volume and flows in order to assess wartime capability. If HQ AFLC develops a transportation model that uses forecast traffic volume and flows as inputs for a network model that is capacitated for dedicated contract service and uncapacitated for nondedicated common service, the model could determine the costs and capabilities of the cargo movement system for any given wartime scenario, assuming the validity of the wartime planning factors (16).

II. Data Evaluation

This chapter presents the background, methodology and findings for research objective #1:

> Determine the reliability, validity and practicality of the empirical data base collected by HQ AFLC/DST.

Prior to developing a statistical description of actual USAF CONUS cargo movement, the empirical data base collected by HQ AFLC/DST must be evaluated. The evaluation addresses reliability of the data, validity of the data, and the practicality of the data collection, as defined by Emory in Business Research Methods (12:128-135).

Summary of Data Collection Plan

This analysis of CONUS cargo movements is based on data collected by HQ AFLC/DST for the period 1 OCT 84 through 31 MAR 85. Shipment data provided by traffic managers at the Air Logistics Centers (ALC) and the Military Airlift Command (MAC), along with shipment data from CONUS Air Force installations not documented by an ALC or MAC, should provide a complete record of all Air Force CONUS shipments during this six month period.

ALC CONUS shipment data was provided through the AFLC Shipment Documentation System (D009) and the AFLC Packaging and Transportation Data System (O013), two automated data collection systems. Retrograde shipment data from MAC aerial ports to CONUS destinations were also provided by an automated data collection system, the MAC Transportation Information Processing System (TIPS). The remaining CONUS Air Force shipment data were manually extracted from record sources by the transportation offices at 77 Air Force active-duty installations and 11 Air Force Reserve installations not co-located with active-duty units. Originally, shipment data from all Air Force Guard units were intended for inclusion in the empirical data base, but a communication break-down prevented inclusion of the shipment data for this thesis. HQ AFLC/DST continues to gather this data, and eventually will include Air Force Guard shipment data in the empirical data base. The data elements for each shipment in the empirical data base included shipment type, transportation consignment number (TCN), consignor, destination, weight, pieces, cube, priority, mode, point of embarkation, special handling requirements, and shipment date. The AFLC automated collection systems, TIPS, and base-level shipment data were reported to HQ AFLC/DST in three different formats, and HQ AFLC/LMTS merged the data from the three sources into the empirical data base used for this thesis.

Methodology for Data Evaluation

Data Reliability. Data reliability concerns the quality or accuracy of the data. The research must distinguish between primary data sources and secondary data sources when evaluating data reliability. Primary source data comes from the original sources of material and allows direct access to data collected to suit the researcher's purpose. Conversely, secondary source data must be transcribed, translated, or manipulated in some way to approximate the researcher's purpose. Since secondary source data was originally collected for other purposes, the data reliability is suspect. A method for evaluating data reliability is measurement of data completeness (12:132).

For the purposes of the research, HQ AFLC/DST has determined that the data collected from the ALCs and MAC can be considered primary source data. The shipment data collected by the D009 and 0013 of AFLC and the TIPS of MAC matches the research purpose for establishing the empirical data base for this study. This purpose is to identify and describe each shipment within the system. Therefore, the shipment data provided by the ALCs and MAC is assumed to be primary data. The reliability of this data was not evaluated in this thesis.

Conversely, the shipment data collected from the base-level transportation offices is considered secondary source data. This shipment data was manually retrieved, compiled from several different sources, and transcribed on floppy disc or magnetic tape in the format specified by HQ AFLC/DST. The extra workload required for the data collection effort, possible compilation and transcription errors, and possible low-priority perception of data collection relative to daily operations by the transportation offices caused HQ AFLC/DST concern about data reliability (13).

Although there was no primary data source for many of the reported data elements on base-level shipments, primary data on the total number of shipments was available for each base through the Traffic Management Workload Reporting and Productivity System (T-WRAPS). T-WRAPS was designed to monitor actual manpower and workload at transportation management offices (TMO). As such, T-WRAPS provides actual counts of surface freight shipments and shipments from the air freight terminal. Comparison of base-level shipments collected in the data base from secondary sources with the primary source total of base-level shipments from T-WRAPS was the basic method used to investigate questions regarding data completeness.

The following questions address the issue of data reliability:

1. What percentage of the shipment data received by HQ AFLC/DST could not be entered into the empirical data base due to transcription and format errors?

2. Based on the number of shipments from the T-WRAPS data for the same six month period, what percentage of USAF CONUS cargo base-level shipments were collected during the manual data collection effort?

3. If the percentage is less than 100%, do the omissions significantly degrade the findings reached using the empirical data base?

Although the total number of CONUS base-level shipments and the number of shipments from selected Air Force bases as documented by T-WRAPS were meant for comparison with the number of base-level shipments in the empirical data base, only T-WRAPS data for Strategic Air Command (SAC) bases were available for the data collection period (34). Therefore, the decision was made to use a convenience sample of SAC bases as an indicator of reliability, but not as a statistical standard. The comparison of total SAC shipments and the variability of comparisons among the SAC bases provided the criteria for assessing the reliability of the empirical data base.

Data Validity. One of the stated purposes of the data collection effort was to use the results of the data collection effort to construct a computer model for determining a movement system that will efficiently meet the Air Force transportation needs (15:2). In order to make that determination, information which will dictate mode and affect price must be available. Therefore, the usefulness of the CONUS Cargo Movement Analysis was dependent on the validity of the data.

According to Emory, validity is the degree that a measurement device correctly measures that which it is designed to measure (12:128). To accurately analyze the data, the proper categories must have been collected. As a group, the categories must explicitly describe each individual shipment. Therefore, there must be enough categories to accomplish the complete description. On the other hand, if extraneous data is collected, redundant or irrelevant information is being used in the analysis. Each is an aspect of data validity; adequacy is the quality which insures complete description, and relevancy is the quality which insures the categories are not redundant or irrelevant. Further description of adequacy and relevancy follows.

Adequacy. Data validity means the data elements collected present a complete picture of the CONUS cargo shipments. Since each piece shipped has certain characteristics, and the composite of the characteristics comprises a complete picture, the data base must encompass a sufficient number of data elements to adequately describe the data base. For example, simply collecting the weight of each shipment is not totally satisfactory for making shipping decisions. Priority, size, and special handling requirements are several additional categories that impact on each movement. Transportation priority dictates the mode that must be selected. Size, weight, and special handling impact on the modes that can be selected. Many common carriers have weight, size or handling limitations. In addition to dictating mode of shipment, this information impacts on the total cost. Most shipments are priced based upon total weight. However, if the weight/size ratio is greater that a set number, then size drives the price. In other instances special handling adds to total cost. Therefore, the data collection effort must collect enough statistics to fully describe the shipment. To determine if there were an adequate number of data elements or variables, the following investigative questions were answered:

1. What criteria dictate the mode a shipment must move on?

2. Which criteria dictate required delivery time?

3. Is there any guidance on determining size and weight break points for shipments?

4. Are there any special categories of information that must be known to determine mode, time constraints, or consolidation?

5. What information must a shipper have before deciding to consolidate hazardous material?

6. Are any guidelines established on categories of shipments that may not be consolidated?

7. What information do commercial shippers use to describe the nature of their cargo movements?

Relevance. Data validity also implies the data is relevant, that is, the categories collected must contribute to a realistic analysis of cargo movement. Each data element must provide new information, not redundant information. In addition, each category must be pertinent to the research objective. Since correlations, presented in Chapter III, were analyzed, any invalid statistical category may jeopardize the usefulness of the findings. An example, admittedly extreme, illustrates this point. If one of the categories collected was age of the shipper, and in the analysis a strong correlation emerged between shipper's age and special handling requirements, the research would be establishing a misleading statistic. Common sense would dictate that Air Force and safety regulations dictate special handling requirements, not age of the shipper. The age of the shipper may affect the ability to classify the shipment properly, not determine a shipment's actual special handling requirements.

Investigative questions answered to determine relevance were:

1. Is the category a logical constraint or input when determining the nature of cargo movements?

2. Is the category a duplication or approximation of another descriptor?

The descriptive categories of shipments actually incorporated in the statistical analysis was determined by HQ AFLC/DST based on the information requirements of HQ USAF/LET. Since determination of the data validity is judgemental, analysis of the logic used by HQ AFLC/DST to insure data adequacy and relevance will be the basis for evaluating the validity of the data used in the CONUS Cargo Movement Analysis.

Data Practicality. A major objective of the CONUS Cargo Movement Analysis was establishing an empirical data base. Time and manpower constraints, along with the current limited reporting procedures for CONUS shipments, led to the decision to use six months of CONUS shipments as a representative sample of CONUS cargo movement. This placed severe limitations on any inferences about annual CONUS cargo shipment characteristics and prevented determination of possible seasonal variance of CONUS cargo shipments. Analyses based on this six months of data must be prefaced with a statement of validity only for this time period. This research study attempts to offer an economical and convenient method for establishing an historical data base that can be used to alleviate these limitations in the future.

Data Evaluation Findings

Data Reliability. Although HQ AFLC/DST managed the data collection effort, HQ AFLC/LMTS assumed the responsibility for merging the data collected from the ALCs, MAC ports, and the base-level transportation offices into an empirical data base for computer analysis. During this process HQ AFLC/LMTS maintained a count of shipment records that could not be input due to format errors.

A preliminary check after input of approximately 80% of the shipment records indicated that 99.4% of the shipment records were accepted into the data base. HQ AFLC/DST considered the small loss of shipment records insignificant to the analysis of CONUS cargo movement because no patterns of omission were discovered. Questions concerning the accuracy of the input data are addressed in Chapter III.

Conversely, comparison of the empirical data base with the Strategic Air Command's (SAC) T-WRAPS data indicates problems with the reliability of the empirical data base. Table 2.1 presents the number of shipments originating from each SAC base according to the T-WRAPS data and to the empirical data base. The percentage of shipments in the empirical data base relative to the T-WRAPS shipments is presented. The same information for SAC is also presented.

TABLE 2.1

Number of Shipments from SAC Bases

Air Force Base	T-WRAPS Number of Shipments	Data Base Number of Shipments	Data Base Number / T-WRAPS Number
Barksdale	17218	5906	34%
Beale	6197	3054	49%
Blytheville	10278	2967	29%
Carswell	11828	6752	57%
Castle	13501	6966	52%
Dyess	10879	5944	55%
Ellsworth	18563	6968	38%
Fairchild	11522	5654	49%
F.E. Warren	1766	842	48%
Grand Forks	15912	4799	30%
Griffis	23540	9904	42%
Grissom	6633	5215	79%
K.I. Sawyer	12126	6470	53%
Loring	15619	4726	30%
Malmstrom	5841	3178	54%
March	3030	2870	95%
McConnell	1834	2079	113%
Minot	6347	5631	89%
Offutt	15902	7004	44%
Pease	9421	6207	66%
Plattsburgh	9619	9254	96%
Vandenberg	1326	923	70%
Whiteman	1640	1168	71%
Wurtsmith	4912	4751	97%
SAC	235163	119232	51%

The 51% SAC total figure is similar to the approximate 50% Air Force total figure HQ AFLC/DST experienced for adjusted fiscal year 1983 and 1984 T-WRAPS data (13). But the large variation between the bases, ranging from 29% to 113%, indicates this is not simply a command phenomenon, but is dependent on the base-level TMO. The wide discrepancy between the empirical data base and the T-WRAPS data limits the conclusions drawn from analysis in this thesis to the empirical data base only, until further investigation determines the reliability of the empirical data base.

Data Validity.

Adequacy. The cat ories of data collected, with a single exception:

1. Accurately describe CONUS cargo shipments.

2. Provide the necessary information for determining mode of shipment.

Based upon review of Air Force shipping regulations and pricing data from common carrier, the essential descriptors of a piece of cargo are origin, destination, size, weight, handling requirements, shipping priority, and hazardous properties (8:3-4). The information for the data collection effort identifies these seven characteristics for each shipment. The data elements, whether broken down by shipment or aggregated, do provide a valid summary. They provide enough information to solve the initial problem set forth in the problem description. The data elements provide the empirical data base that meets the analytical needs of the Air Force. Within this context the data is valid.

The second purpose of the data base was to support research to reduce transportation costs. For this objective, the data must be sufficient to determine the optimum mode. The data collected, again with a single exception, provide the parameters for identifying mode. Therefore, once cost and performance characteristics are collected the selection of optimum mode is possible.

Air Force Regulation (AFR) 75-1 is the source of transportation policy governing mode selection. Basically, the policy is to choose the least expensive mode that will adhere to the Uniform Materiel Movement and Issue Priority System (UMMIPS) standards, subject to a few restrictions. Given the flexibility, the Air Force traffic manager can select the mode that is most effective and efficient (8:4-1).

The restrictions in AFR 75-1 are:

1. For shipments greater than 1000 pounds, the shipper must request routing instructions from the Military Traffic Management Command.

2. If a shipment is greater than 1000 pounds, the Air Force cannot use commercial air.

3. The following types of shipments cannot be consolidated:
    a. hazardous material
    b. ammunition or explosives
    c. project material from different projects
    d. radioactive or magnetic material
    e. parts for a grounded aircraft
    f. expedited handling requisitions
    g. unlike perishable goods or goods with different expiration dates (8:3-4,3-5)

DOD Directive 4500.32, Vol 1 requires the DOD shipper consider the following characteristics in selecting a mode of transportation:

1. Required delivery date

2. Nature of material

3. Weight

4. Size

5. Distance (7:3-6)

Each of the variables identified in DOD Directive 4500.32 has been addressed in the data collection effort.

The single exception referenced previously is the failure to be more specific on hazardous material characteristics. Since all hazardous materials are not subject to the same restrictions, simply knowing if a material is hazardous does not fully describe the shipment options available to the traffic manager. The governing federal directive, the Code of Federal Regulations (43:100-177), lists each hazardous material individually, and then accompanies that listing with applicable restrictions. For example, some material is prohibited aboard any passenger vehicle or cargo plane, while other material is only prohibited aboard any passenger vehicle, and for some material the restrictions only apply when a set amount is exceeded. Therefore, simply knowing that a given shipment is hazardous does not allow selection of a carrier, without specifically knowing the transportation restrictions.

An additional element that should be incorporated into the data base is the distance from origin to destination. That information need not be collected, but simply incorporated as a matrix from which the data base could draw. Distance is important for determining when truck can be substituted for air and still meet a deadline standard. Since truck is generally less expensive and has easier access, and can travel 300-500 miles per day, that option is available for Transportation Priority 1 (TP 1) cargo. Unless distance is available, the choice cannot be made.

Relevancy. The corresponding issue to adequacy is relevancy. Each category in this data collection effort is unique and pertinent. No categories are sources of redundant information.

Data Practicality. Development of CONUS cargo movement strategy not only requires a current empirical data base that describes CONUS cargo movements, but also an historical data base that supports statistical forecasting techniques to determine future CONUS cargo movement requirements. The data collection effort for this study required a tremendous expenditure of time and manpower by HQ AFLC/DST and the data sources. As discussed in the Chapter I background section, a computerized transportation information and cargo processing system for all Air Force traffic managers would improve the efficiency of CONUS cargo movements and provide an efficient means for shipment documentation. Air Force standardization of computer-based shipment documentation and reporting procedures could provide relatively simple maintenance of the empirical data base for future CONUS cargo movement analysis.

III. Analysis of CONUS Freight Shipments Using Exploratory Data Analysis

This chapter presents the background, methodology, and findings for research objective #2:

> Determine the nature of USAF CONUS freight shipments by summarizing the appropriate statistics, analyzing the relative and cumulative frequency distributions, and determining the empirical relationships between key variables.

Before using any of the data collected in a model, a basic understanding of the data set's characteristics is required for two reasons. First, as established in Chapter I, a final distribution system can be based upon complete LOGAIR service, complete common carrier service, or a combination of services. However, unless the decision maker has an understanding of the types of shipments the system must support, he/she cannot ascertain which alternative can satisfy the demands. A summary of the appropriate statistics and analyzing the appropriate frequency distributions will be the basis for this understanding.

Second, if a modeling effort is to be undertaken the model must be developed to accommodate any interrelationships between variables. For this study the relationship between weight and volume of each shipment was analyzed. A model of the transportation system can incorporate demands by weight, volume, or a combination of the two. Transportation companies generally employ a "cube rule." That is, price is governed by weight, unless the volume, in cubic feet, is greater than ten times the weight, in pounds. If that volume standard is exceeded, then the shipper is billed based upon the volume price. The example of shipping a plane load of ping pong balls shows why the "cube rule" is used. Unless the modeler understands how the two characteristics interrelate, the decision on how to represent transportation system inputs will not be based upon the variable that governs price.

Specifically, the following questions will be answered for the 1.3 million shipments contained in the data base:

1. What do the descriptive statistics reveal about shipment weights?

2. What do the descriptive statistics reveal about shipment volume?

3. What do the descriptive statistics reveal about number of pieces in a shipment?

4. What do the descriptive statistics reveal about shipment priorities?

5. What inferences can be drawn from the relative and cumulative frequencies for weight?

6. What inferences can be drawn from the relative and cumulative frequencies for volume?

7. What inferences can be drawn from the relative frequencies for number of pieces?

8. Are size and weight related?

After the initial statistical analysis, a second more specific analysis is required. The decision maker must be able to separate those shipments that are eligible for common carrier from those shipments that cannot be carried by a common carrier. The shipments that cannot be handled by common carrier are candidates for a contract carrier, such as LOGAIR. The second section of this analysis addresses that issue, using the following research questions to reach the objective.

1. What types of shipments can be carried by any or all common carriers?

2. What types of shipments cannot be carried by any or all common carriers, even though the carriers can accommodate the weight, because that common carrier is not capable of delivery within the established UMMIPS time standards?

3. What do the descriptive statistics reveal about the types of shipments identified in questions 1 and 2?

4. What do the relative and cumulative frequencies reveal about the types of shipments identified in questions 1 and 2?

5. How do size and weight relate for the shipments identified in questions 1 and 2?

Although the types of shipments that cannot be carried on board a common carrier can be determined, the actual percentage of these shipments cannot be computed. Since one of the factors which dictates mode is time, common carriers are selected on their ability to meet time constraints. One factor in determining the ability to meet the time constraint is distance. If a shipment must arrive in 3 days and only has to travel 1000 miles, then truck could be used. However, if a shipment had to travel 2500 miles in 3 days, then only airborne modes of transportation could be used. In the second case, truck could not be a viable alternative to a contract carrier. The data base does not include distance to be shipped as one of the elements. Therefore, which shipments could substitute land modes for air modes, and still meet time constraints, cannot be directly determined.

Theoretical Approach to Exploratory Data Analysis

The approach to answering the research questions and reaching the research objective will be explained in the next two sections. The first section explains the theoretical approach to examining the data base. The approach starts with selecting the level of analysis required, and then selecting the method of analysis to attain that level. The second section, methodology, presents the specific steps taken in this research to answer the research questions.

As this research is the initial investigation of the characteristics of CONUS cargo movements, an approach must be selected which emphasizes open ended analysis. Also, the approach should not present findings which may distort the true picture of the data set. The approach is dependent upon the level of statistical description. The levels being indication, determination, and formal inference. The following section will present a synopsis of the three levels.

Levels of Statistical Description. The levels of description the least restrictive to the most conclusive are:

1. Indication
2. Determination
3. Formal Inference

Indication. At this level only primary statistics are computed, similarities between groups of numbers discussed, and trends or inequalities presented. No attempt is made to treat uncertainty or draw any statistical conclusions. Sometimes analysis stops at the indicative level. Several valid reasons are:

1. Data sources mask important sources of variability.

2. Difficult to handle substantial differences in variability that comes from a multiplicity of variables.

3. Preliminary investigation has lead to a few indicators for later analysis (21:25-30).

<u>Determination.</u> If indicative statistics are not completely satisfactory for analysis, the next level is determination. The determinant level attempts to treat the uncertainty that was not addressed in the indicative stage. Usually estimates of the variation or standard deviation are the statistics used to show central tendency, and remove some of the uncertainty. Still no statistical inferences are drawn.

<u>Formal Inference.</u> The third and final level, formal inference, addresses the uncertainty through precise mathematical models. Inference passes judgment on a statistical hypothesis or defines a confidence interval.

<u>Approaches to Data Analysis.</u> The approach to data analysis is a function of the level of statistical description desired. Exploratory data analysis is most appropriate for indication and determination, while confirmatory analysis best addresses the requirements of formal inference.

Exploratory Data Analysis. Exploratory data analysis has three basic guiding principles. First, exploratory analysis attempts to isolate patterns and features of the data. The patterns and features that are isolated should be those that are readily apparent to the researcher. Since exploratory analysis is the first contact with the data, the second principle is that the study should be accomplished without any preconceived model or end objective in mind. Finally, the entire approach must be flexible. As stated previously, this analysis is the initial summation of the data, and therefore, the researcher must be prepared to express the results as he/she uncovers them, not as he/she would think the results should be expressed.

With those three principles, the data is analyzed using three techniques:

1. Use of resistant statistics
2. Residual Analysis
3. Reexpression of scale or exponents

Use of Resistant Statistics. The first important principle of exploratory analysis is using statistics that are not susceptible to significant influence from outliers. Since the general nature of the data is not understood, using statistics that are easily misinterpreted can lead to false conclusions. For example, expressing central tendency in terms of the median, and not mean, will minimize the impact of extreme values.

The next principle, residual analysis, separates the data into two separate categories. Hartwig refers to the categories as smooth and rough (20:10). The smooth component is the general nature or classification of the data. Smooth is the "underlying, simplified structure...the general shape of a distribution or pattern in the data (20:10)." The rough component is the residuals remaining after fitting the data to certain smooth descriptors. Rough is an appropriate analogy, because after fitting the data to smooth characteristics, the residuals remaining should not have any pattern. If a predictable pattern remains, then the initial smooth description is either inaccurate or incomplete.

Residual Analysis. Residual analysis is important in two separate areas: presenting descriptive statistics and analyzing regression results. In presenting descriptive statistics, the greater the degree of conformity within the data set, the more confidence could be placed in the findings. The behavior of the residuals provides clues to the conformity. The data set may lend itself to a smooth histogram or a smooth distribution. However, since any data set can be presented as a histogram or distribution, the closer approximation to a recognizable pattern the more useful that pattern when used in summarizing. If residual analysis leads to the conclusion that no pattern exists within the data, that is a significant finding as well.

The second area of residual analysis is regression. The impact of the residuals is more fully addressed under the assumptions of the regression model. However, in regression if the residuals or "rough data" retain a pattern then either the incorrect regression model has been selected or the data is deterministic. In either case the researcher has been provided valuable information to consider before using any findings.

<u>Reexpression.</u> Finally, the data may be more easily understood by reexpressing the exponents of variables used in the analysis. The objective of reexpression is equalizing the spread of the data points. The various groups of batch data may be more easily interpreted if the the spreads are all commensurate (20:33). The data should provide indications when reexpression may be appropriate.

Four viable indications are:

1. The batch data shows strong asymmetry.

2. There are numerous outliers in one tail.

3. Difficult to compare groups of data because of the spread.

4. Large residuals result from fitting the data to a model (21:97).

Any reexpression must preserve the integrity of the data and not distort the results. Reexpression is an aid to reaching conclusions about the data, and therefore, should not impact negatively on the analytical process. Any decision to reexpress must weigh the advantages gain versus the use of a more unfamiliar scale. With that premise in mind, any reexpression must:

1. Preserve order

2. Preserve the median

3. Maintain continuity

4. Provide smooth curves

5. Use as simple a function as possible (21:99)

Confirmatory Analysis. The second method of data analysis, confirmatory analysis, is used when ever formal inference is selected as the level of statistical description. The move to this level of statistical description would be required for four separate objectives:

1. Formulating hypotheses

2. Developing confidence intervals

3. Applying conclusions from one set of statistics to a second set

4. Validating a conclusion by collecting and analyzing a new data set (21:2,212)

Methodology for Exploratory Data Analysis

Of the three levels of statistical analysis available in exploratory data analysis, indicative, determinant, and confirmatory, the emphasis was upon the indicative and determinant levels of description. The data analysis to achieve the indicative and determinant levels of description was conducted in three distinct phases:

1. Analyzing the entire data base

2. Analyzing all Transportation Priority 1 (TP 1) shipments

3. Analyzing only Mission Capability (MICAP) shipments

Analyzing the entire data base provided a comprehensive picture of CONUS freight shipments. Analyzing TP 1 shipments provided clues to the types of shipments that must meet short deadlines. Since TP 1 has a UMMIPS suspense of 3 days (7:3-13), the shipments in this category will move by air, assuming the distance is further than a truck can move in 3 days. The air shipment can be by common carrier for those shipments that are capable of being handled by common carrier, while the remaining population must be delivered by the contract service. Understanding the characteristics of this subset, and understanding the capabilities of common carriers gives the decision maker an indication of the type of contract service that must be provided.

MICAP, a special category of TP 1, is defined by AFR 75-1 as:

> Pertaining to those critically needed items with transportation priority 1 that are requried to remove primary weapons and equipment from mission capability (MICAP) status (8:34-4)

MICAP is an important subset, because these deliveries cannot wait for contract transportation, if a more expeditious mode is available (8:34-9). Therefore, analyzing this subset will provide an insight to the shipments that must move quickly. As AFR 75-1 directs, shipment planning is based upon the transportation that provides the earliest delivery to the customer. Therefore, understanding MICAP characteristics will provide the decision maker with an understanding of those types of shipments that must move immediately, and do not lend themselves to any economies of scale (8:34-9).

Within each phase were three separate areas of analysis:

1. Interpreting the initial descriptive statistics.

2. Viewing the relative and cumulative frequencies.

3. Determining any relationships among the variables specified in the initial research questions

Initial Descriptive Statistics. The descriptive statistics for weight, volume, number of pieces and priority were analyzed for the three separate groups listed previously: all shipments in the data base, all TP 1 shipments, and MICAP only shipments. These statistics provide the initial clues to the characteristics of each variable.

The summary statistics were generated by the AFLC Create system using the entire population of shipments collected. For the period 1 Oct 84 to 31 Mar 85, the collected data represents the entire population of USAF CONUS cargo shipments. As a sample, it is not necessarily representative of any particular population of USAF shipments, either for this calender or past calender years. Statistical Package for the Social Sciences (SPSS), version 9 (31), was used to produce the results. Several limitations of the software were encountered. The problems resulted from SPSS being designed for social science research, and being difficult to adapt to a data base that contained many unique values on a scale that approximated continuous values.

A decision to put a restriction on the values for weight and volume was made after two initial runs. Only shipments that were less than 10,000 pounds and 1001 cubic feet were included. Without eliminating shipments greater than those values, values of 99,999 pounds, 9999 cubic feet, and 999 pieces would be values used in the statistical analysis. As will be explained later, the assumption was made that the values of all 9's came from a misunderstanding of the reporting instructions, rather than representing a reliable figure. While it may be possible that the Air Force has moved shipments in excess 100,000 pounds and 1000 pieces, it is very unlikely that these were MICAP shipments as the priority codes indicated. Especially, since AFR 75-1 states that:

> MICAP must be single shipped, and not consolidated under any conditions (8:34-9).

The reporting instructions that accompanied the collection effort dictated that bases put all 9's in a field if the value exceed the largest a field could contain. However, after studying the results of the computations, it appeared that some sources were using a field of all 9's to indicate missing data. Therefore, the assumption was made that the data was not usable, and 10,000 pounds and 1001 cubic feet selected as the upper limits.

Table 3.1 table shows the maximum field size for the three quantifiable variables that were collected: weight, volume, and number of pieces. For example, if a shipment contained 10,500 pieces, the entry in the pieces column would be 9999, since only four digits were allocated to

Table 3.1

Field Sizes for Quantifiable Variables

Variable	Field Size	Largest Possible Value	
Weight	6	999,999	pounds
Volume	4	9,999	cubic ft
No. of Pieces	4	9,999	pieces

their field. Therefore, the assumption was made that the reporting instructions were not properly followed, because these values still appeared when the analysis was limited to only MICAP shipments.

Table 3.2 shows the difference in summary statistics with the upper limit omitted and the upper limit imposed. The table reveals very little difference for the median values between the population with the 10,000 pound/1001 cubic feet upper limit and the population without any restrictions. However, the means are radically different. A few large values would tend to skew the means, but not distort the median.

Table 3.2

Comparison of Statistics with and without Limitations Placed on the Maximum Acceptable Value

	Without Limitations	With Weight and Volume Limits
Weight (pounds)		
Median	12.236	12.021
Mean	198.367	119.598
Volume (cubic feet)		
Median	1.844	1.797
Mean	18.847	11.830

Relative and Cumulative Frequencies. Although the six month data collection effort represents the entire population for that six months, identifying the underlying statistical distributions provided the framework for understanding the variable's characteristics. Analyzing the frequency distributions was the first step in identifying the underlying statistical distributions.

Fitting any empirical data to identifiable distributions had two major benefits, as opposed to simply using only plotted empirical data. First, sample data may not pick up any of the extreme values in a population. The limits of the empirical data were the two extreme points. That is, no values greater or less than the extremes would appear, even though some of those values had a probability of occurring. Identifying an underlying distribution would allow extreme values to be considered with the proper probability of occurrence.

The second benefit of fitting empirical data to a statistical distribution was that samples were only single values, but a distribution provides a framework. The fewer the number of values in a category the more difficult the task describing that category, unless a distribution can be applied. Stating a statistical distribution and its parameters presents a complete picture. The principle of separating the smooth from the rough (20:10), as explained in the previous section, is accomplished in this analysis.

Although fitting data to a known distribution had two major benefits, only data that can be accurately fit should be put into a distribution. Forcing data into an incorrect distribution would diminish the accuracy of instrument to which the data is input. For example, a bi-modal distribution has a mean and variance, but using its mean and variation and assuming normality will invalidate any results.

Since the emphasis of this research was at the indicative and descriptive levels of statistical description, only subjective analysis was accomplished. Further research should be directed at testing the hypotheses at appropriate levels of significance. The frequency distributions were then plotted, and after being combined with the summary statistics an underlying distribution was hypothesized. The frequency distributions for weight, volume, number of pieces, and priority were all obtained. In addition, the same distributions were obtained for the three separate populations: all shipments, TP 1, and MICAP only.

Relationships Between Variables. The final investigative questions in each section was answered by understanding the relationships between variables. If a strong relationship exists, then an additional understanding of the nature of cargo shipments is possible.

The benefits of understanding the relationships, in addition to aiding the modeling effort, were several:

1. Provided a summary set of statistics along with interacting categories

2. Analyzing relationships provided clues for eliminating a specific category confusing the analysis.

3. Strong relationships provided a starting point for further research into causal relationships.

4. Interrelationships provided a starting point for prediction and forecasting (21:110)

A summary set of statistics provided additional insight into the nature of cargo movements. The fact that light weight shipments go by air may be important to establish. However, by introducing another independent variable, such as MICAP, additional information may be gained about the light weight shipments that travel by air.

In contrast to the first step, a variable that appeared to have an influence on the nature of a shipment may only be clouding the issue. Using the same example as above, by studying relationships the result may be that there is absolutely no relationship between the fact that a shipment is light, and the probability that it will travel by air. Trying to correlate them may only cloud the analysis. That provided a valuable piece of information by removing ambiguous variables.

Thirdly, establishing a statistical relationship would point the direction for a researcher that may be looking for cause and effect between variables. A strong correlation provides an excellent starting point for research.

The final benefit of understanding any interrelationships in the variables was being able to forecast and predict. Understanding the nature of the past shipments could only be beneficial when applied to future transportation demands.

Understanding the relationships between variables has the four benefits listed above, however the major benefits for this thesis are numbers 2, 3, and 4.

Three findings or conclusions could be reached from this analysis. Attempting to use the analysis for any of the three would have led to incorrect conclusions.

First, establishing the relationships between variables confirmed that by knowing certain characteristics about one or more independent variables, the researcher has information about a dependent variable. That is, he/she has more information than knowing nothing about the independent variables. However, that is the only conclusion that can be drawn. Unless further research is undertaken, the analyst cannot state that the independent variables cause the result.

Second, the established relationships are valid only for the data collected. The results cannot be generalized to a large population. For example, if a certain relationship was uncovered between variables describing Air Force CONUS shipments, attempting to assert that the same relationship characteristic is then true of DOD shipments would be an invalid use of the results. Further statistical testing would be required before making that assertion.

Third, extrapolating to determine a characteristic is an invalid technique. The analysis is conducted between two extremes, and any further testing must also remain between the extremes.

The primary method of determining relationships between variable was simple linear regression. Regression provided the benefits of analysis listed earlier, and the technique also contained the shortcomings. Although linear regression can be a valuable tool for estimation and prediction the emphasis will be upon estimation. This section will present the major steps in the regression analysis.

There are basically three steps in the regression process. First is verifying that the data base does not contradict any of the assumptions required to use the regression model. Second, a regression model must be developed using the variables from the data base. Third, and this step must occur interactively with the second, as models are being developed determine the criteria for selecting the optimum model.

Assumptions. For the final regression model to be a valid tool, six assumptions were validated.

1. The model was correctly specified

2. Predictor values were not randomly generated, but are under control of the researcher.

3. Error terms had a mean equal to zero.

4. Error terms were uncorrelated.

5. Error terms had a constant variance.

6. Error terms followed a normal probability distribution (16:140)

Assumption 1: A valid model must include all relevant variables, and be free from irrelevant terms. The first objective of the thesis was validating the characteristics of the cargo movements. If that analysis has substantiated the characteristics, then all relevant terms have been identified. Further analysis will be accomplished to determine which of the characteristics should be expressed as interactive terms with other variables and which of the characteristics must be reexpressed using logarithms or exponents.

Assumption 2: Regression is a deterministic model, not a probabilistic approach, therefore any randomness of inputs invalidated the approach. To eliminate or minimize random variables, two requirements must be met. First, all data was accurately recorded or at least capable of being accurately recorded. Second, the inputs were controlled by the researcher, not merely observed (16:171). Again, fulfilling the initial objective was important to verify this assumption. By establishing the reliability and completeness of the data, all data could be assumed to be correctly recorded. Secondly, all shipments entering the CONUS cargo system were within the control of the US Air Force, and therefore were capable of being controlled by the user.

Assumption 3: The method of computing the least squares line in the regression forces the mean of the error term to be zero. If the mean were not zero, then by definition the line being analyzed would not be the least squares.

Assumption 4: Uncorrelated error terms were in essence independent error terms, since independence requires uncorrelated terms that are normally distributed, and normality will be addressed in assumption six. Independence could be virtually assured by use of random data points from the sample. Independence and lack of correlation are more difficult to establish with time series data. The time span of data collection was not long enough to be considered a time series data base.

Assumption 5: As in assumption 4, by using an independent samples from the same population this assumption was not violated (16:171).

Assumption 6: Assuming normality allows confidence intervals to be constructed. Regression could be used without this assumption, but confidence intervals for estimators and predictors would be biased.

Approach to Building Regression Model. Once the assumptions had been validated by analyzing each one, an appropriate regression model was constructed. Using the variables that were validated in the first section an appropriate linear equation was constructed. The initial equation contained all validated quantitative and qualitative variables. In addition to those first order terms, certain second order terms must also be considered. Second order terms would include both interactive and exponential expressions.

After progressing through the steps listed in the approach to model building and completing a subjective analysis of the needs of the decision maker, the only relationship that was important was that of weight and size.

Therefore, the regression that was computed was a simple linear regression with weight as the independent variable and volume as the dependent variable.

Exploratory Data Analysis Findings.

As explained in the methodology section of this chapter, the analysis was carried out in three separate phases, and therefore, will be presented in three separate sections. The analysis of all CONUS freight shipments is first, followed by the analysis of all TP 1, and finally the results of the MICAP portion of the TP 1 data set.

All CONUS Cargo Shipments. The four relevant quantifiable variables are weight, volume, number of pieces, and priority. These four combine to describe the unique physical characteristics of each shipment. The first portion of the findings section addresses these variables. The relationship between weight and volume is presented second. The final section is an overview of the types of shipments that the Air Force makes.

Weight. The frequency distribution for weight approximates an exponential distribution. For example, the largest percentage of shipments for any single value is for one pound and the percentage values taper off consistently from that point. Since all weights greater than 20 pounds are less than one percent, Figure 3.1 shows the distribution for less than 20 pounds only. This cutoff more explicitly shows the frequencies which are greater than one percent.

Looking at the cumulative percentiles, which are resistant statistics, the 25th percentile falls between 2 and 3 pounds. The median is 12.021, and the 75th percentile is at 82 pounds, with 99% of all shipments falling below 2000 pounds. Table 3.3 shows how these percentile weights correspond to the percentile weights for TP 1 and for MICAP.

Table 3.3

Comparison of Percentile Values

Category	25th	50th	75th	99th
		Weight (Pounds)		
All Shipments	2.6	12.02	44.0	1655
TP-1	2.5	12.34	47.0	230
MICAP Only	2.4	6.72	30.0	1115
		Volume (Cubic Feet)		
All Shipments	<1	1.79	4.5	160
TP-1	<1	1.58	5.0	270
MICAP Only	<1	1.39	3.0	158

Figure 3.2 shows the cumulative distribution for all weights less than 100 pounds and Figure 3.3 displays the cumulative distribution for less than 1000 pounds.

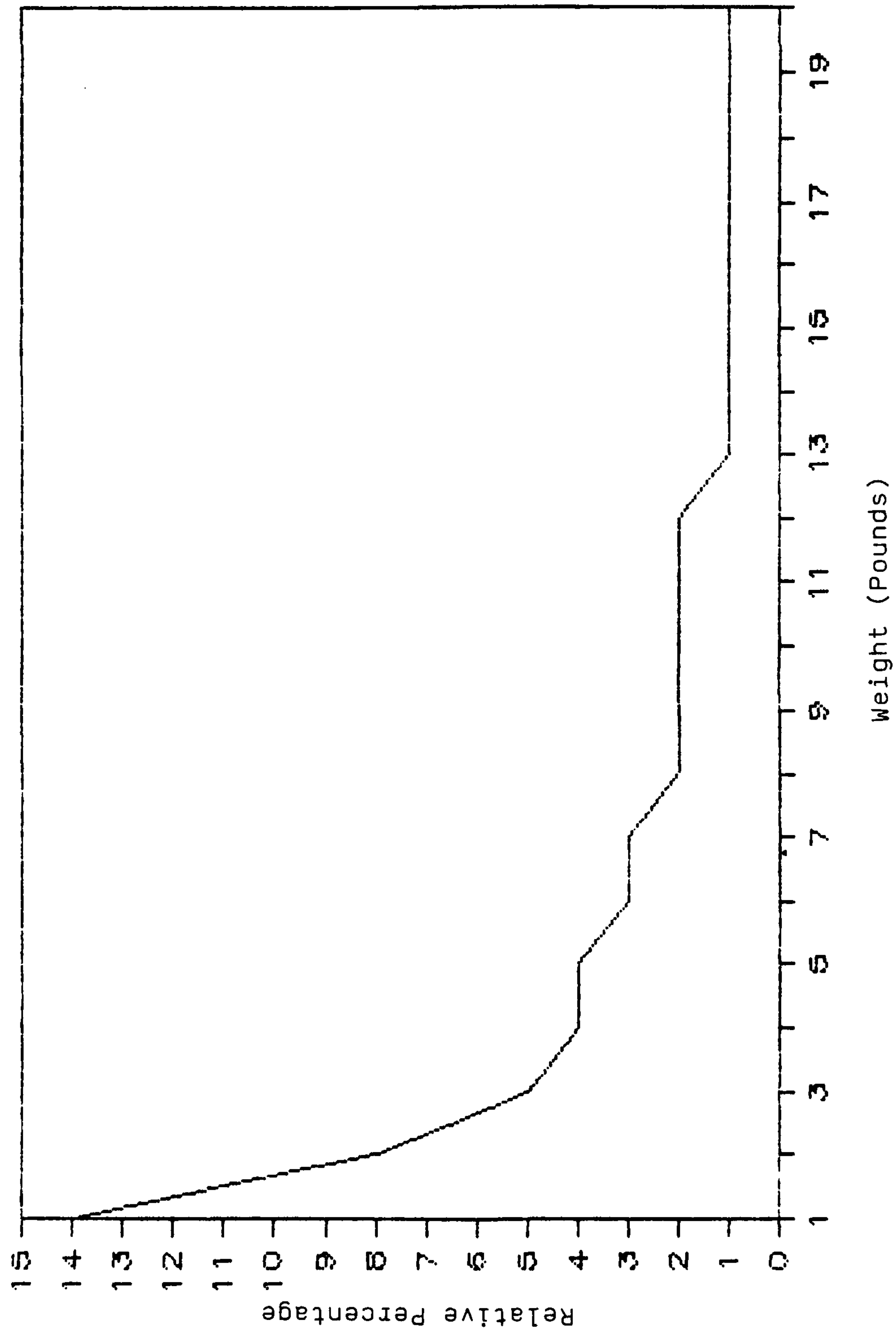

Fig 3.1 Relative Frequency by Weight
All CONUS Shipments 1-20 Pounds

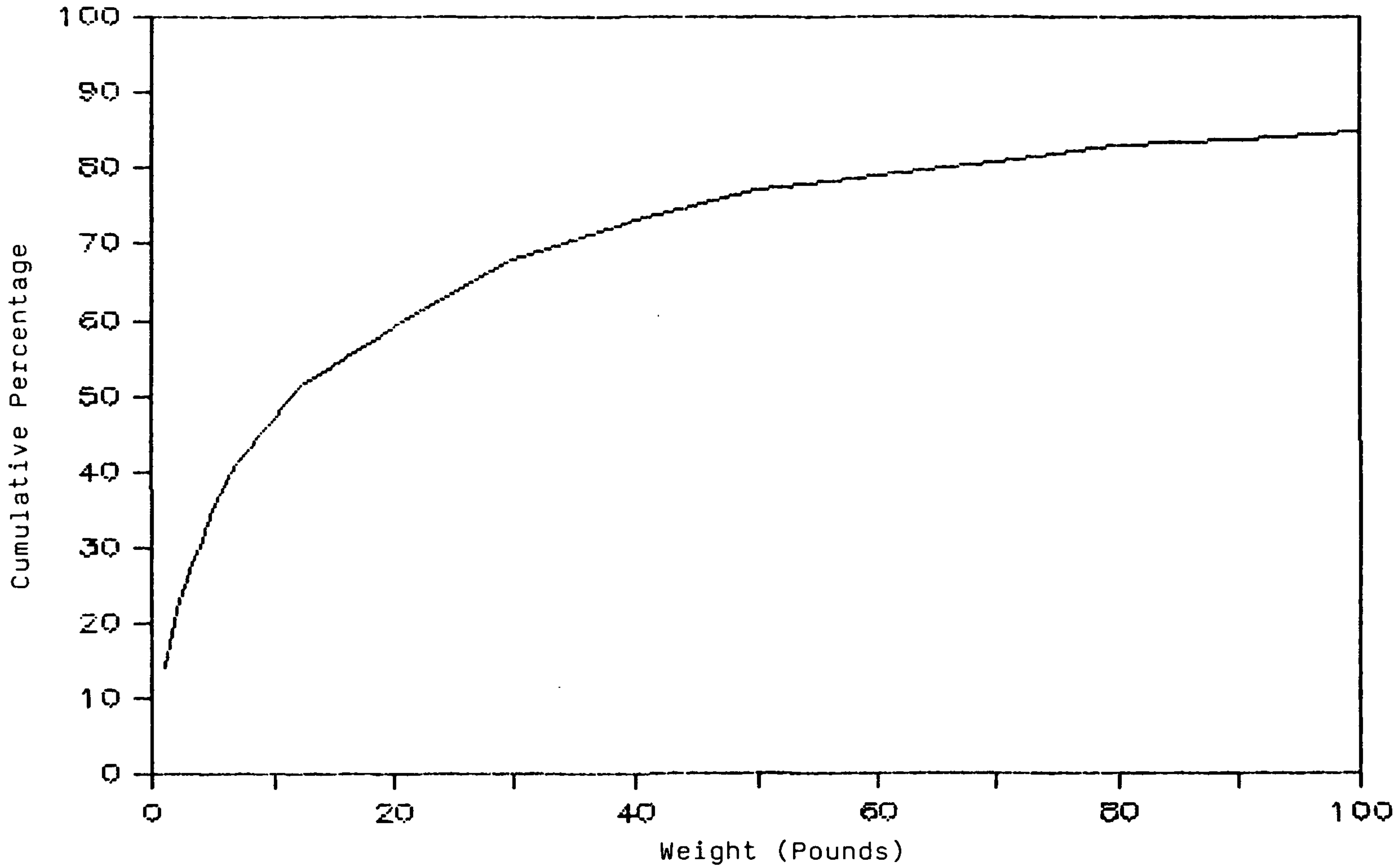

Fig 3.2 Cumulative Frequency by Weight
All CONUS Shipments 1-100 Pounds

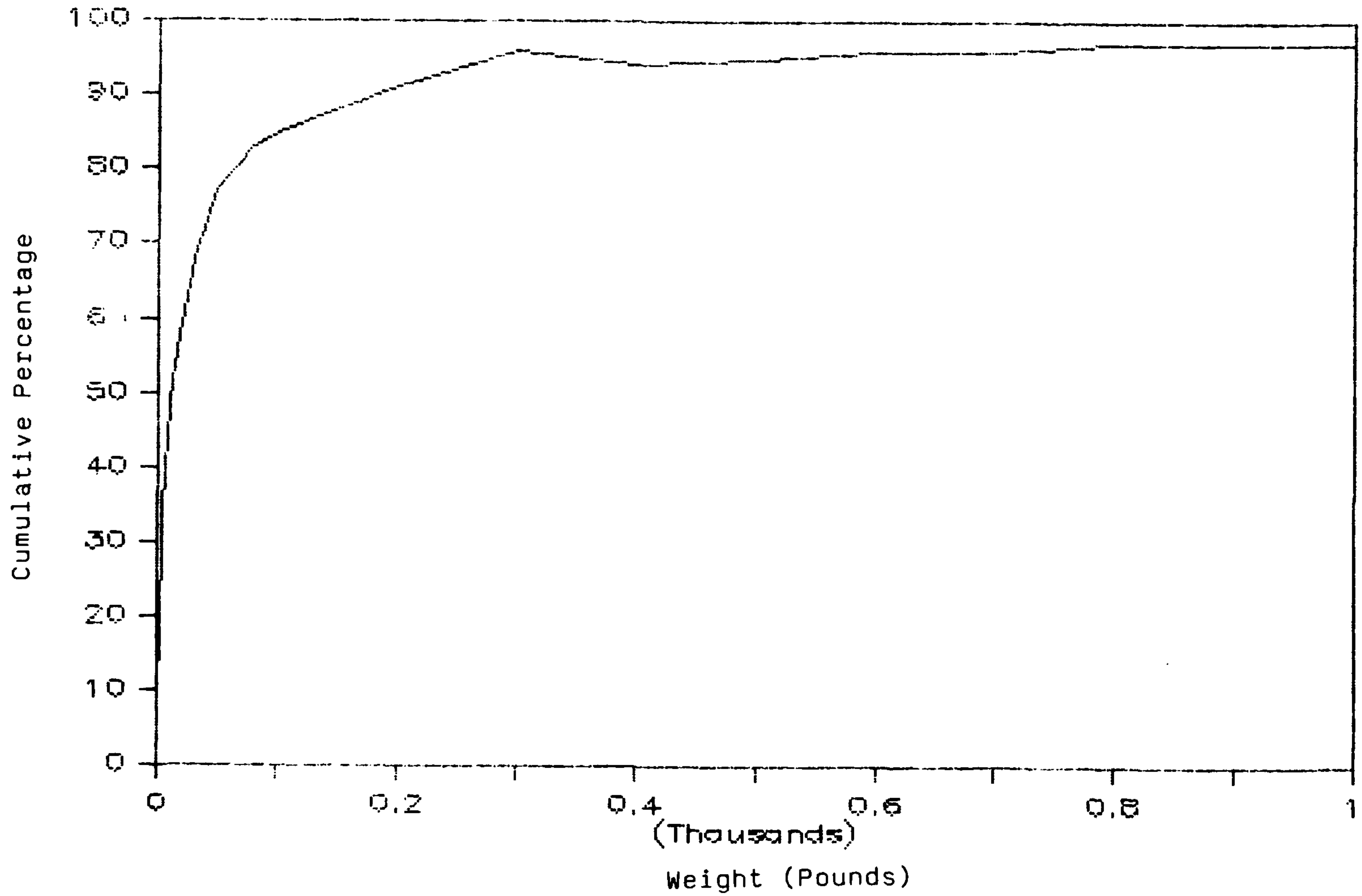

Fig 3.3 Cumulative Frequency by Weight
All CONUS Shipments 1-1000 Pounds

As expected with an exponential approximation, the mean and the median are not closely related:

mean=119.568 pounds
median=12.021 pounds

Since the emphasis is on use of resistant statistics, as explained in the exploratory data analysis section, the median provides a more meaningful interpretation.

Volume. The volume histogram also approximates an exponential distribution, with the mode being 1 cubic foot and accounting for 46% of all shipments. Figure 3.4 is a relative frequency graph of volume for all shipments. As with the weight relative frequency, only values less than 20 were included in the the relative frequency plot. All values greater than 20 cubic feet had a relative frequency of less than 1. Figure 3.5 is the cumulative distribution plot for all volumes 100 cubic feet or less. percentile values are presented on Table 3.3 and compared to the other two analyses. One interesting note is that 90% of all shipments are 16 cubic feet or less, but the 99th percentile is not reached until 160 cubic feet. The maximum value in this run was 1000 cubic feet.

Pieces. 97% of all shipments were one piece; 99% contained 5 or less pieces.

Priority. Priority is distributed according to Table 3.4

Table 3.4

Priority Distribution

Priority	Relative Frequency (Percentage)	Cumulative Frequency (Percentage)
MICAP	11.7	11.7
1	31.9	43.6
2	34.0	77.6
3	20.9	98.5
4	1.5	100.0

Relationship between Weight and Volume. The r-squared term for the regression was .64608, meaning that the error term in the regression accounted for about 35% of the value of the sum square of the dependent variable. Weight was not a perfect predictor of volume, but is of some value.

Classification of Cargo Shipped. The data collection effort identified certain commodities that were shipped during this six month period. Specifically, the following commodities were found in the population:

Aircraft parts and engines	43%
Hazardous material	2%
Classified shipments	1%

Note: These categories are not necessarily mutually exclusive.

Selecting Additional Groups to Analyze. Since one of the stated purposes was to provide an understanding what cargo must be carried by a dedicated, contract system as opposed to cargo that could be handled by common carrier, that differentiation was the key to selecting additional

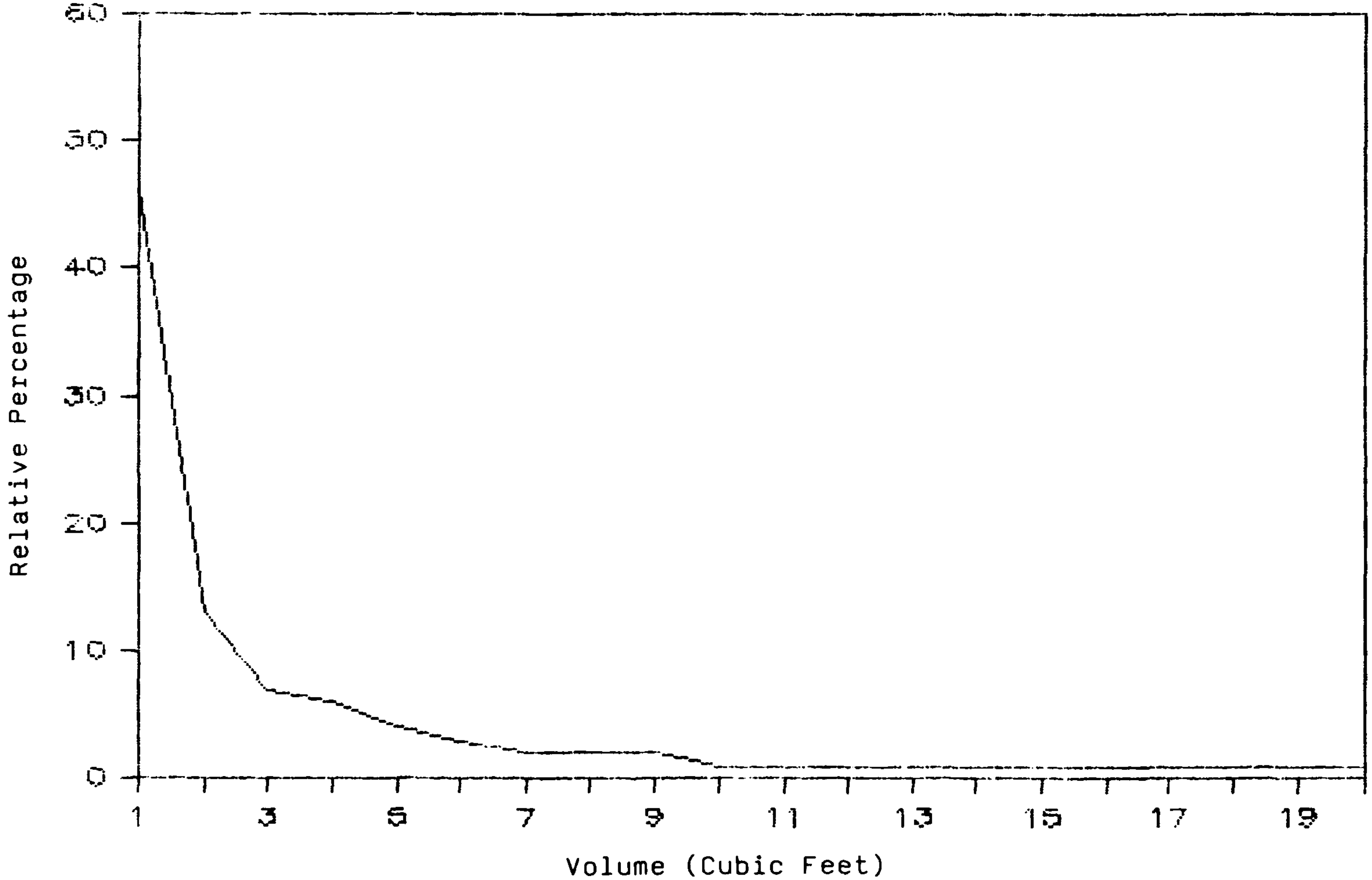

Fig 3.4 Relative Frequency by Volume
All CONUS Shipments 1-20 Cubic Feet

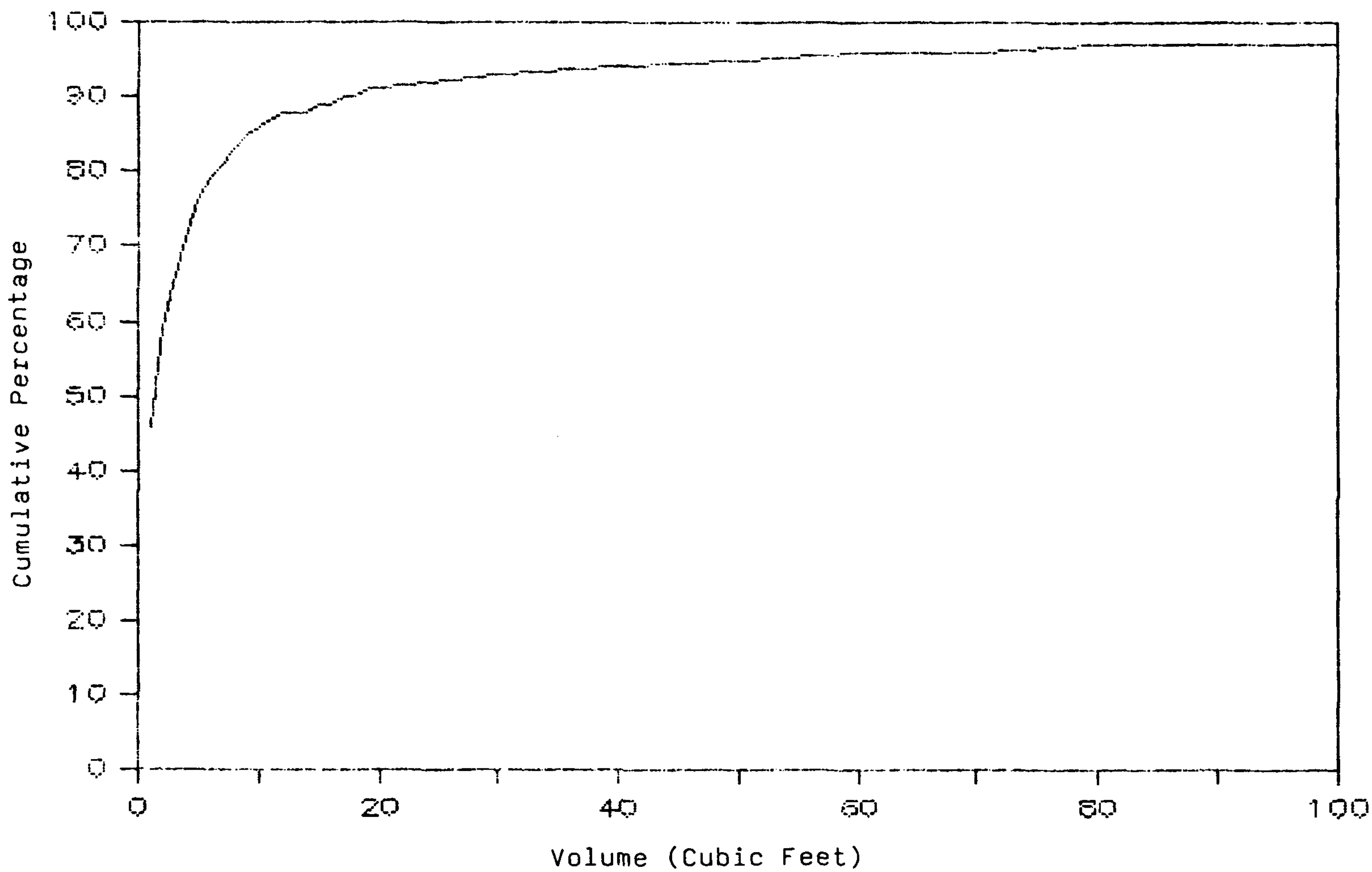

Fig 3.5 Cumulative Frequency by Volume
All CONUS Shipments 1-100 Cubic Feet

subset statistical analysis. Basically, the two important subsets to statistically analyze are TP 1, and the MICAP subset of TP 1. The justification for this selection follows.

Most common carriers have weight restrictions. All United States Postal Service and United Parcel Service (UPS) packages, for example, are limited to 70 pounds. Federal Express has a 150 pound limitation. Above the 70 and 150 pounds shipments, the common carriers that can accommodate larger sizes do not publish common carrier tariffs, but charge by contract pricing. That is, the shipper contracts for the shipment and is not using a published tariff by a common carrier. Since a final model developed would have to differentiate between common and contract rates, the assumption was made that common carriers can only handle shipments of 70 pounds or less (150 pounds for Federal Express). The final mode, less-than-truckload (LTL), can accommodate the 10,000 pound maximum weight included in this study.

The next constraint is time. MICAP must be delivered by the "transportation method that provides the earliest delivery to the customer" (8:34-4), TP 1 within 3 days, TP 2 within 6 days, and TP 3 within 13 days (7:3-13). Combining the two constraints, Express Mail and Federal Express would provide the most responsive service for MICAP, but are limited to 70 and 150 pounds respectively. Air Parcel Post can be used, in addition to the previous modes, for TP 1. Surface parcel post and regular UPS delivery can accommodate

TP 2 and TP 3, but are limited to 70 pounds. Less-than-truckload can carry any size, and can travel 300-500 miles per day. Therefore, LTL is capable of handling almost all TP 2 and TP 3, and TP 1 within 900 miles. In specific instances, LTL is actually faster for MICAP.

A dedicated service must be able to handle those cargo requirements that are outside the limits in the above paragraph. For the purposes of this thesis, the dedicated service must be able to handle:

1. All MICAP greater than 70 pounds (150 pounds if Federal Express is available).

2. All TP 1 greater than 70 or 150 pounds that must travel more than 900 miles

3. Any hazardous or classified shipments

The data base did not include distance for the shipment to travel in any of the fields nor was there an easy method to compute the distance for the 1.3 million pieces. Therefore, TP 1 shipments that could meet the time restrictions by truck could not be identified. To insure a complete picture, the assumption was made that the dedicated service must handle all TP 1 cargo greater than 70 pounds regardless of distance. As explained under the nature of cargo shipments previously, hazardous and classified material shipments are so insignificant, they will not impact on the structure and demand of a dedicated transportation network.

Therefore, the statistical analysis looked at TP 1 initially, and then MICAP alone, to determine how much of the data base could be handled by common carrier.

Transportation Priority 1. This section presents a summary of the characteristics of weight and volume for TP 1 with an emphasis on explaining how the findings relate to common carrier capability. Table 3.3 compares some of the results to comparable statistics for the all CONUS freight shipments, and the MICAP only shipments.

Weight. The distribution is similar to that for all the shipments. Figure 3.6 shows the relative frequencies for all weights less than 20 pounds. Again, all weights over 20 pounds had a relative frequency of less than 1. Fifteen percent of all shipments are less than one pound. The 25th percentile falls between 2 and 3 pounds, the median is 12.268 pounds, and the 75th percentile is 47 pounds. Table 3.3 contains the comparison to the other two groups (all CONUS shipments and MICAP). Again, as should be expected with this distribution the mean and median are separated:

mean=147.405 pounds
median=12.268 pounds

Fiqure 3.7 shows the cumulative frequency distribution for 100 pounds and less. Figure 3.8 is a cumulative histogram for 1000 pounds and less. Basically, at least 84% of all TP 1 can be carried by common carrier, and of the remaining 16% any shipments of less than 900 miles can also be handled by common carrier LTL. The dedicated service must be directed at the 16% greater than 70 pounds that

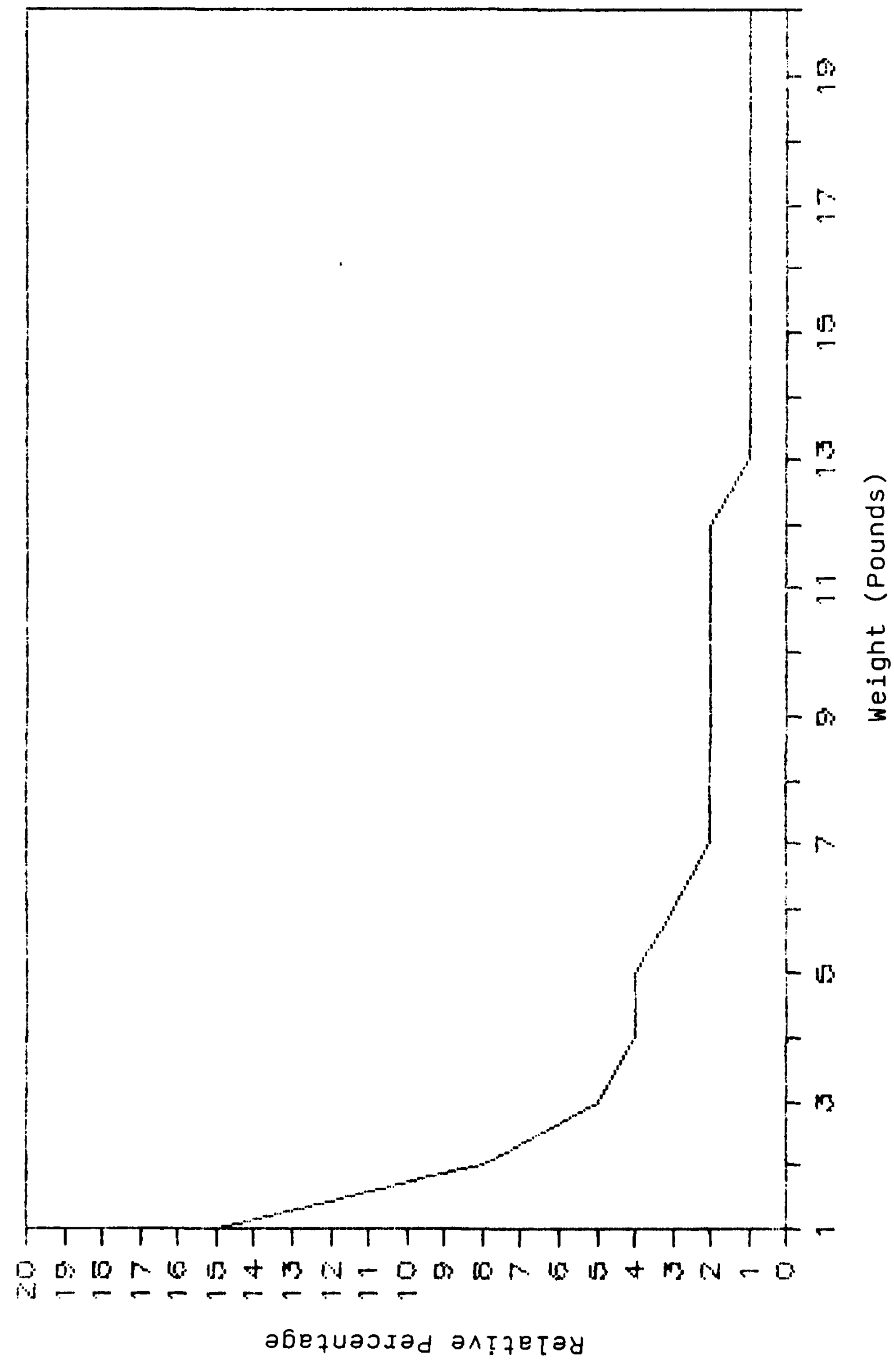

Fig 3.6 Relative Frequency by Weight
All TP 1 Shipments 1-20 Pounds

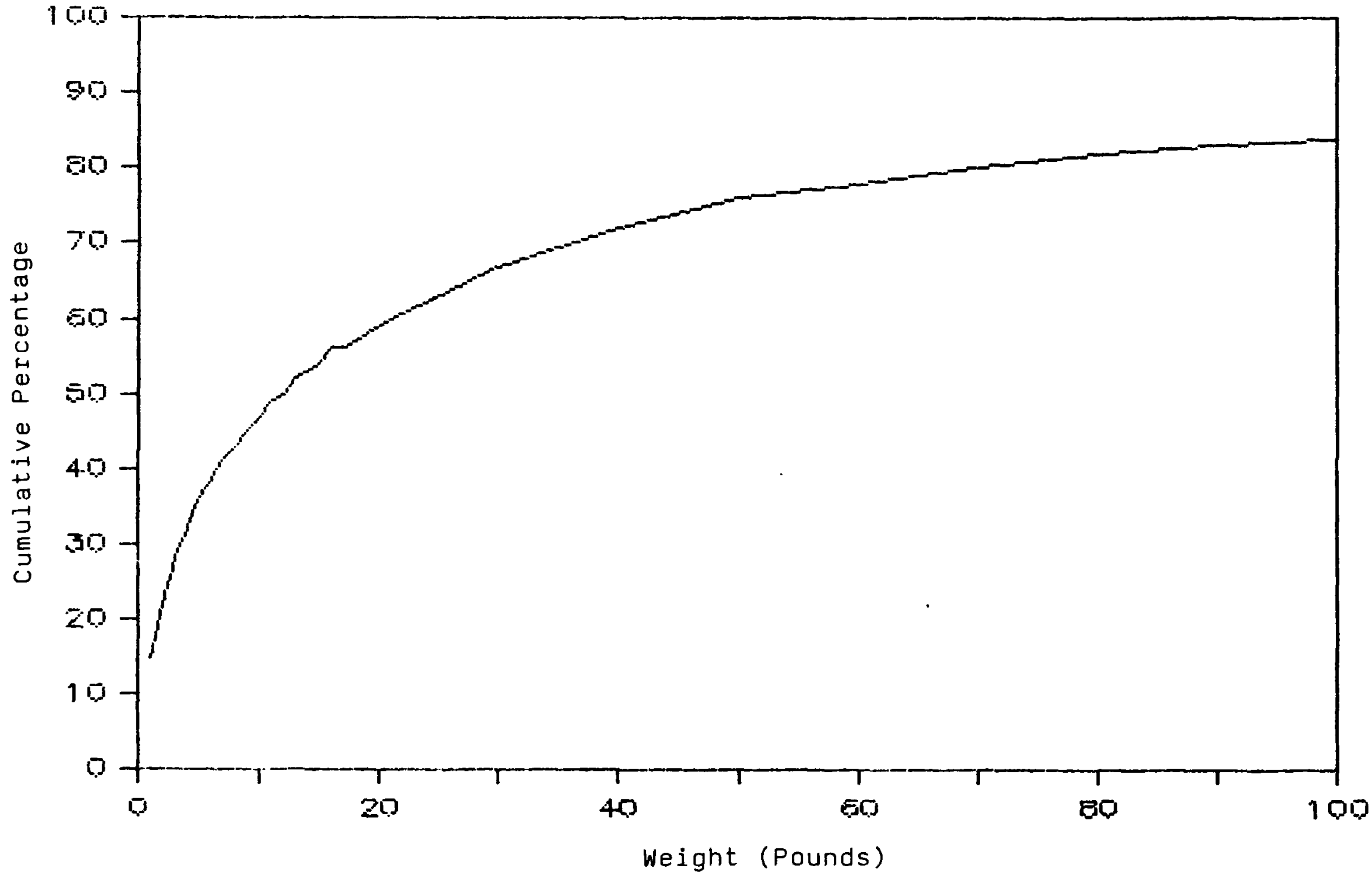

Fig 3.7 Cumulative Frequency by Weight
All TP 1 Shipments 1-100 Pounds

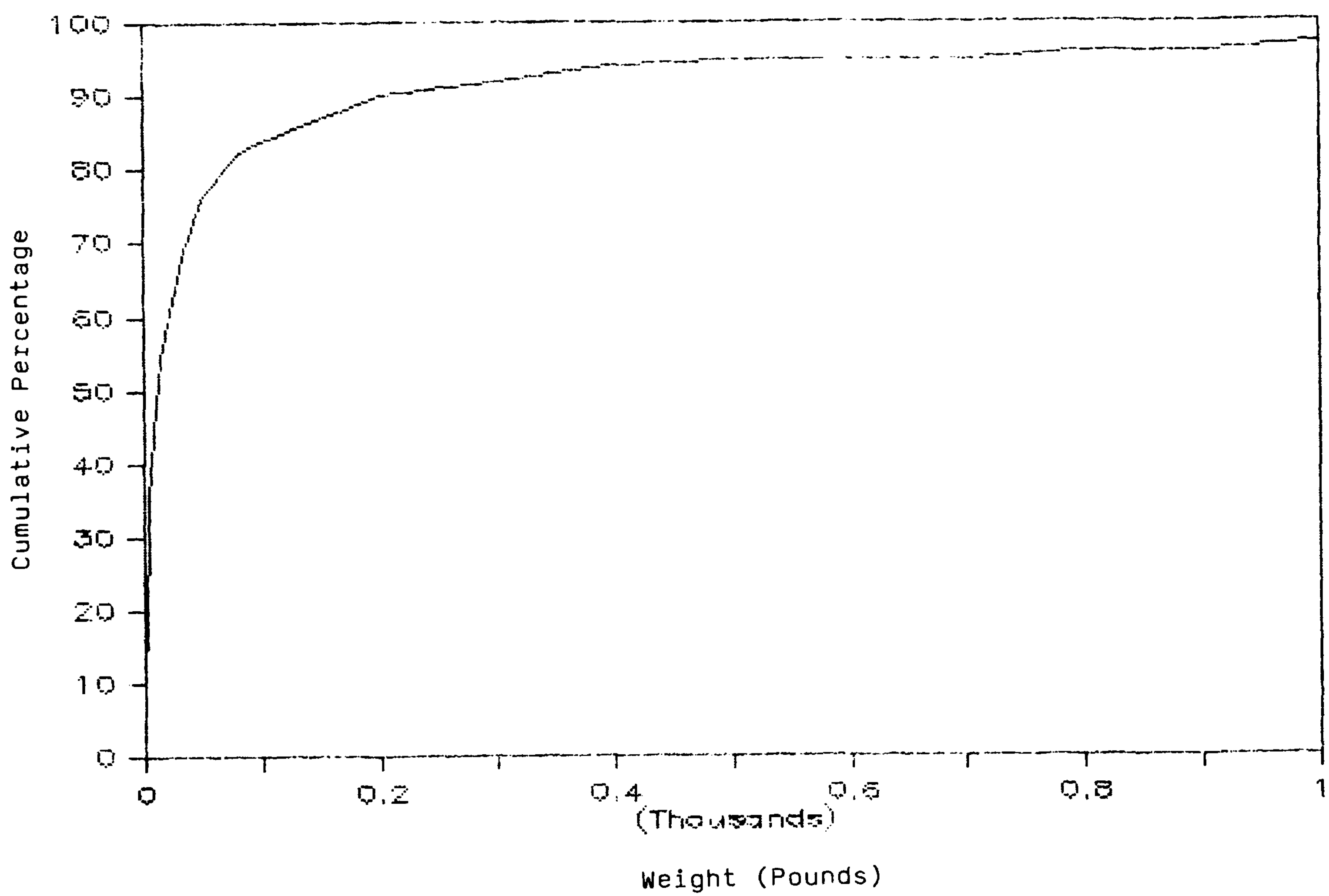

Fig 3.8 Cumulative Frequency by Weight
All TP 1 Shipments 1-1000 Pounds

cannot move by truck in a timely manner.

Volume. The relative frequency plot of volumes less than 20 cubic feet approximates an exponential distribution (Fig 3.9). Forty-six percent of all TP 1 shipments are one cubic foot or less. The median is 1.830, the 75th percentile is 5 cubic feet, and 99% of all shipments are 270 cubic feet or less. Table 3.3 shows a comparison to all shipments and MICAP shipments.

Figure 3.10 is the cumulative frequency graph for TP 1 shipments of 100 cubic feet or less.

Relationship of Weight to Volume. Within this subgroup, weight becomes a better predictor of volume. The r squared term has increased to .70001.

MICAP. Of all three categories, the most responsive and timely distribution system must be MICAP. No specific time limit is placed upon delivery, only the requirement that the shipment be delivered by the most expeditious means (8:34-4). This section which describes the characteristics of the shipments which demand this expeditious handling.

Weight. As with the two previous sections, the relative frequency distribution for 20 pounds or less resembles an exponential distribution, with 21% of all MICAP shipments being 1 pound or less (Fig 3.11). The 25th percentile falls between 1 and 2 pounds, the median is 6.67, and the 75th percentile is at 30 pounds. Table 3.3 shows how these percentiles correspond to the populations

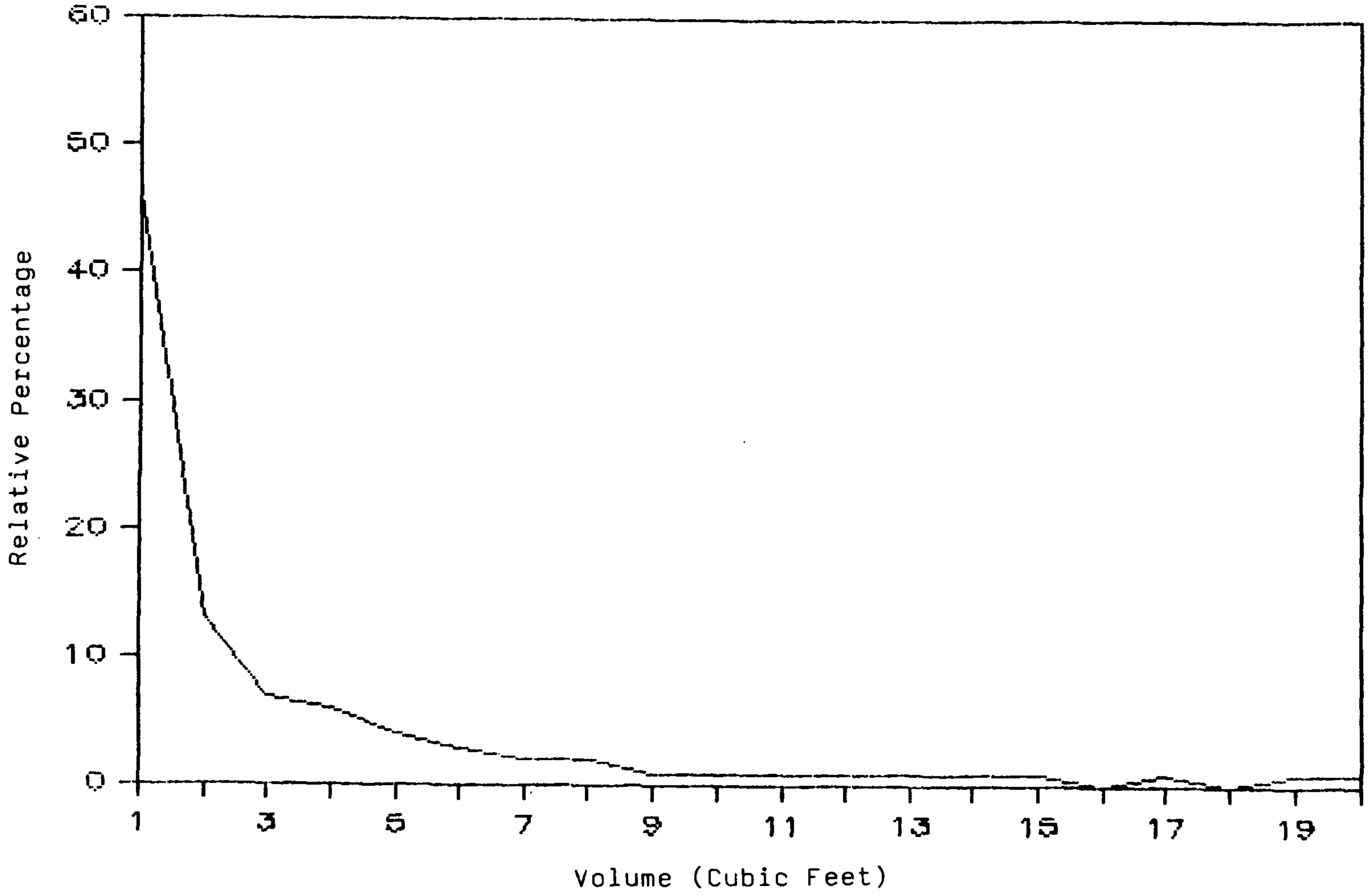

Fig 3.9 Relative Frequency by Volume
All TP 1 Shipments 1-20 Cubic Feet

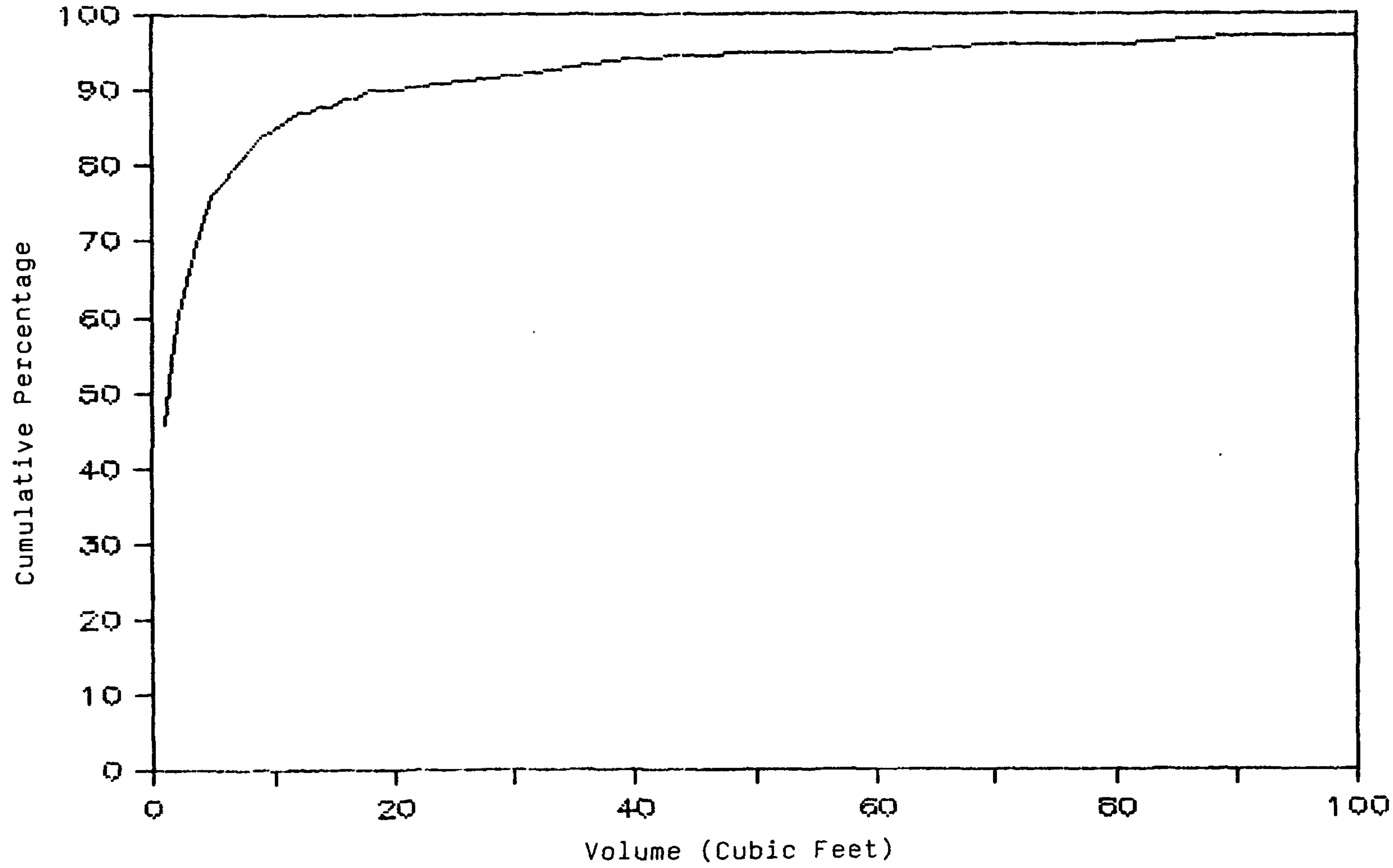

Fig 3.10 Cumulative Frequency by Volume
All TP 1 Shipments 1-100 Cubic Feet

containing all CONUS freight shipments and MICAP only shipments. Also, the median and the mean are not closely related:

mean=104.7 pounds
median=6.67 pounds

The cumulative frequencies for MICAP shipments by weight show that at least 85% of all shipments can be handled by common carrier (Fig 3.12). Taking into account the 150 pound limit for Federal Express, the percentage increases to 88%. If the shipment can move expeditiously by truck, or common carriers increase their limitations, then a greater percentage can be carried by common carrier.

Figure 3.13 is the cumulative frequency graph for MICAP shipments of 1000 pounds or less.

Volume. The relative frequency plot for volume has the same basic distribution as weight for MICAP shipments and volume for the other two groupings. Figure 3.13 shows the relative frequency distribution for all volumes 20 cubic feet or less; with 56% of all shipments being one cubic foot or less. The 25th and median fall at less than one cubic foot and the 75th percentile is 3 cubic feet. Table 3.3 shows the volume comparisons.

Relationship of Weight to Volume. As a predictor of volume, weight for MICAP is about the same as weight for all TP 1. R squared is .69208.

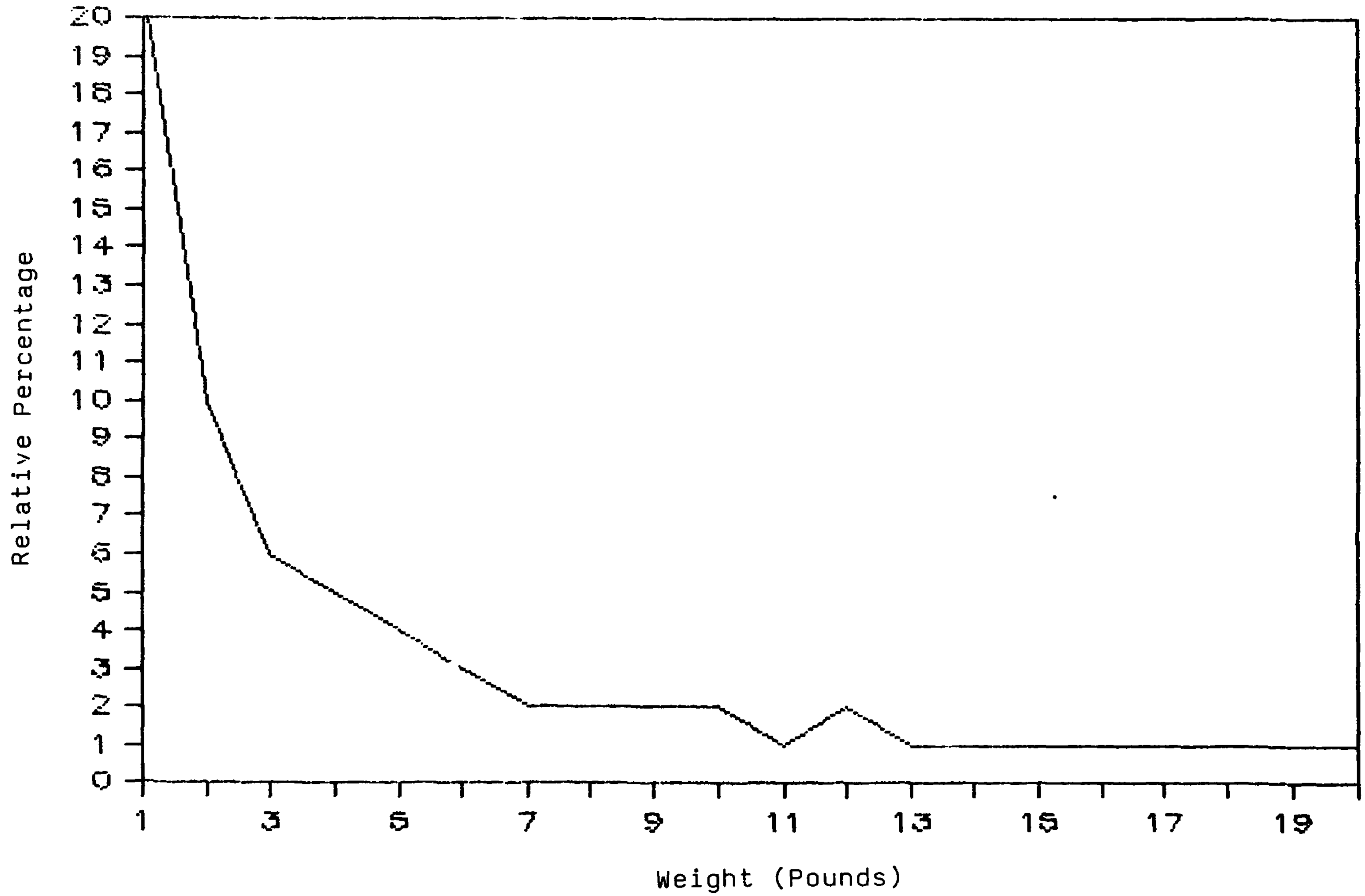

Fig 3.11 Relative Frequency by Weight
All MICAP Shipments 1-20 Pounds

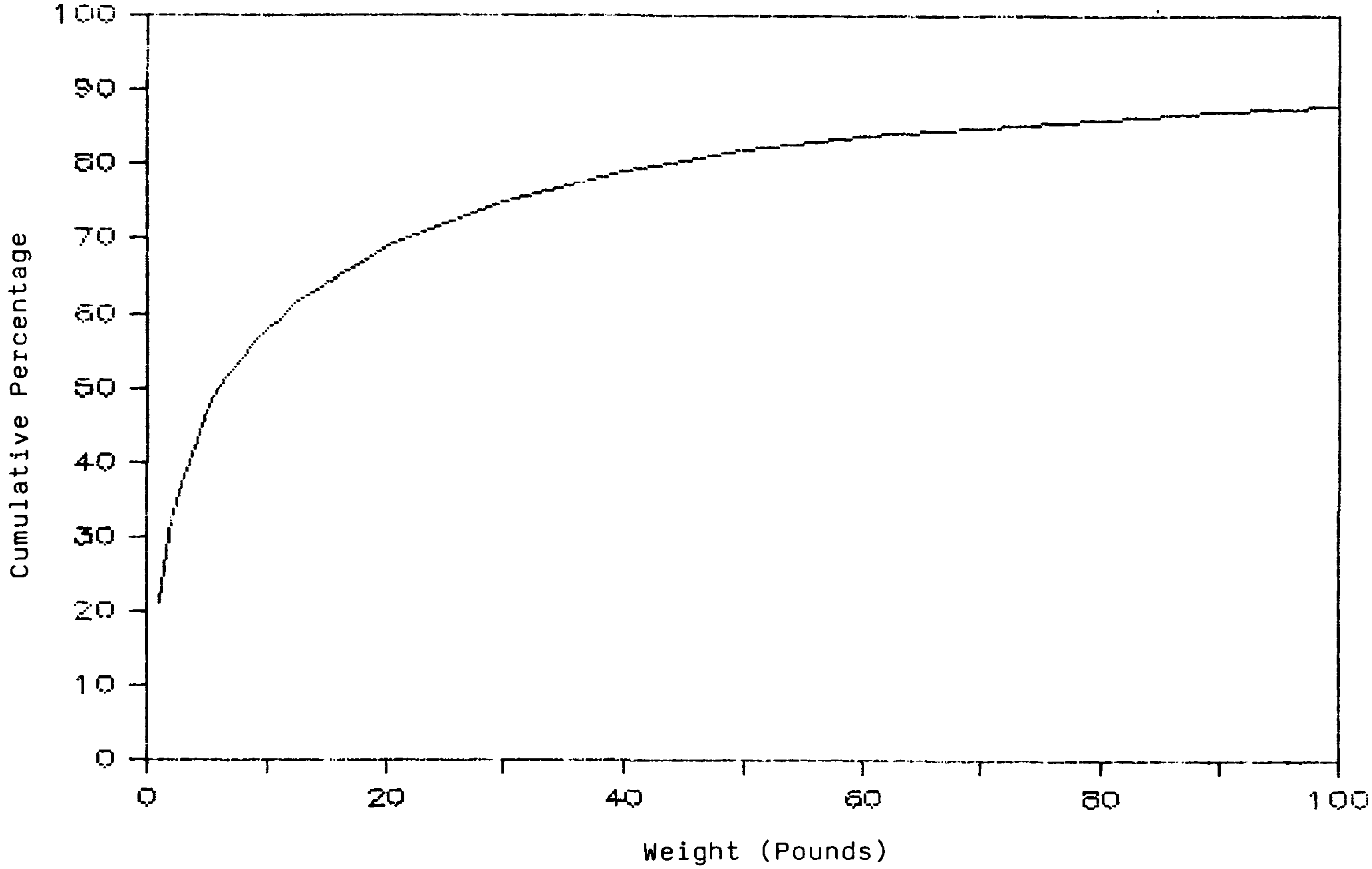

Fig 3.12 Cumulative Frequency by Weight
All MICAP Shipments -100 Pounds

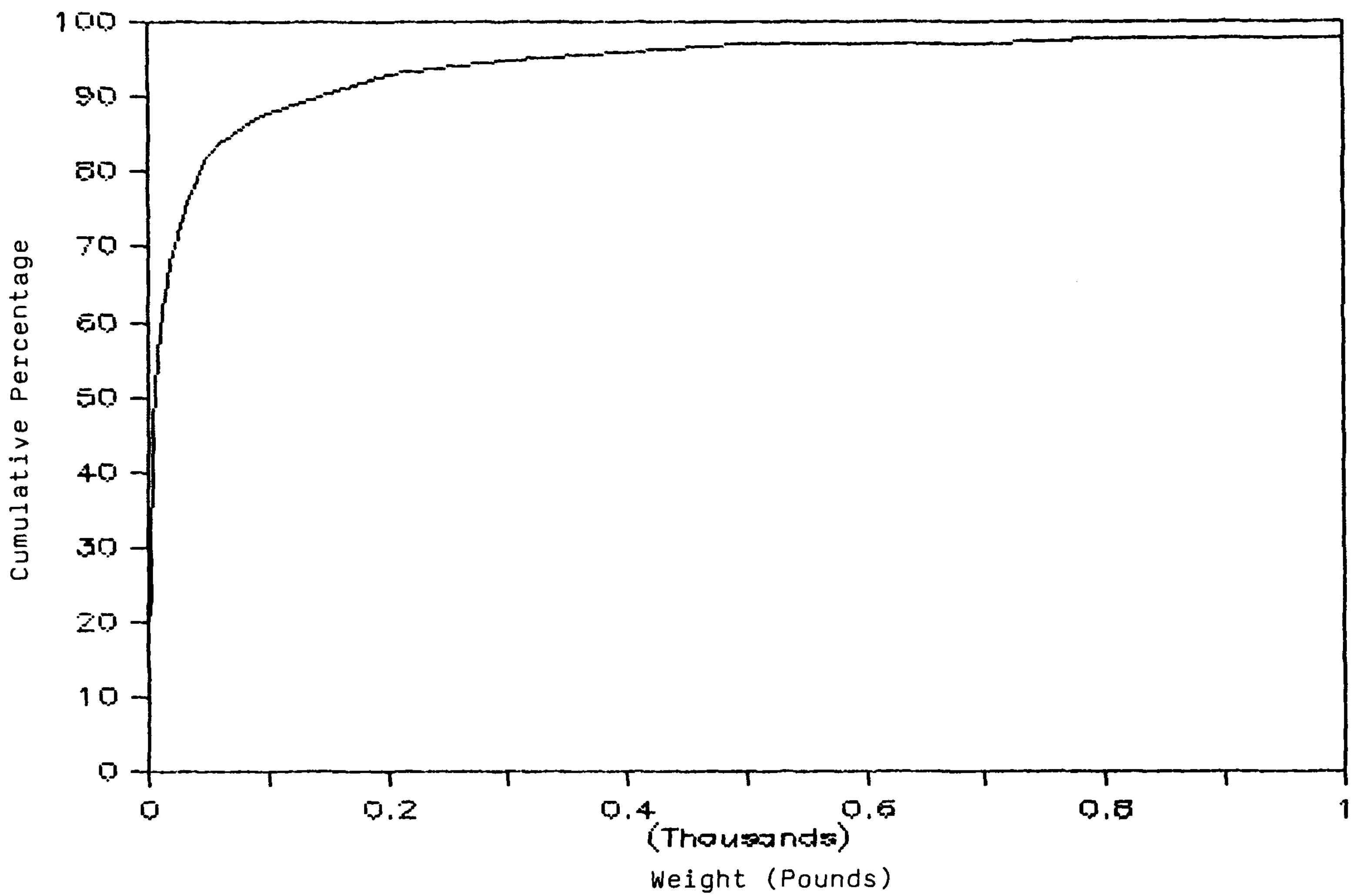

Fig 3.13 Cumulative Frequency by Weight
All MICAP Shipments 1-1000 Pounds

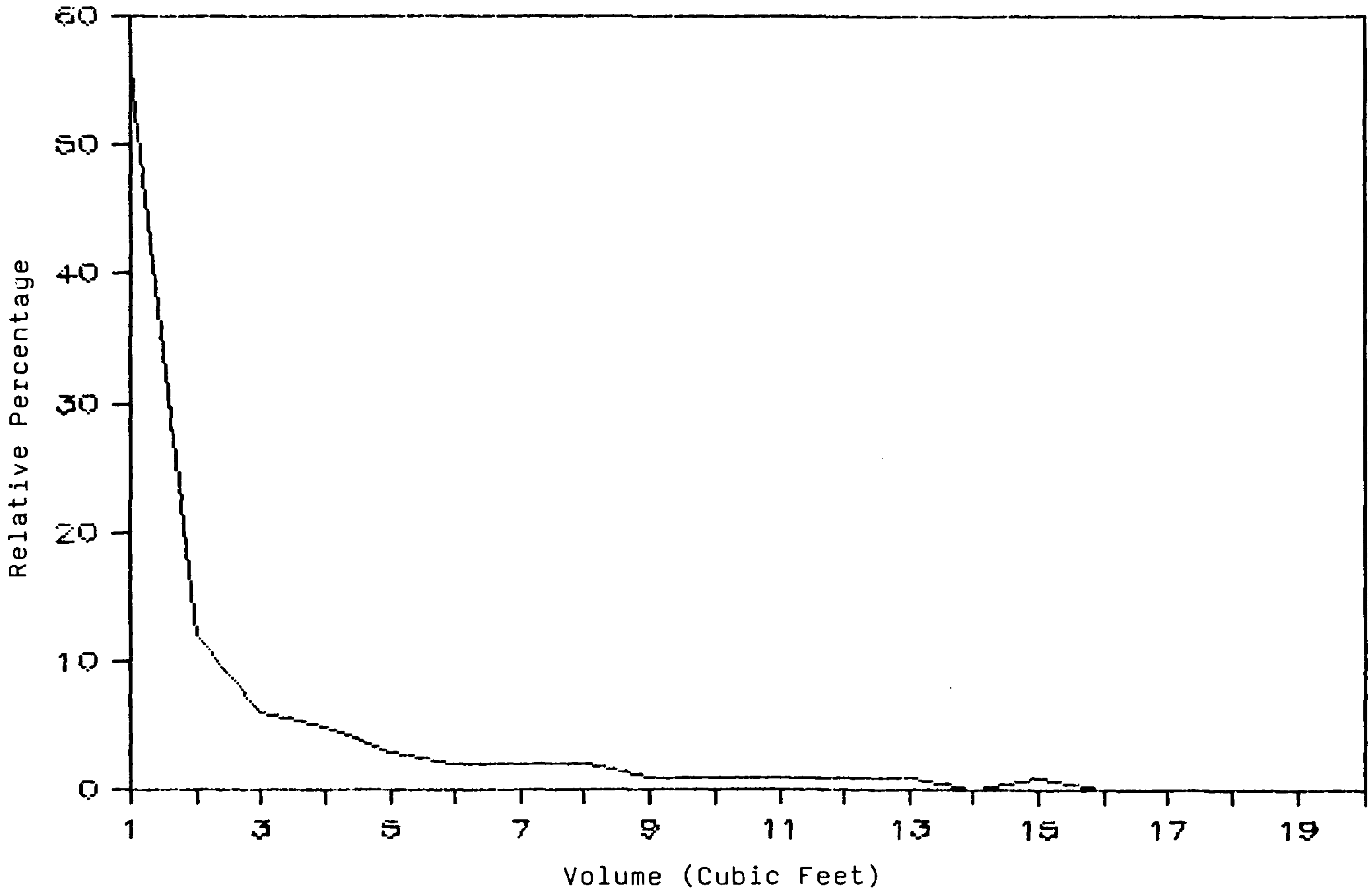

Fig.3.14 Relative Frequency by Volume
All MICAP Shipments 1-20 Cubic Feet

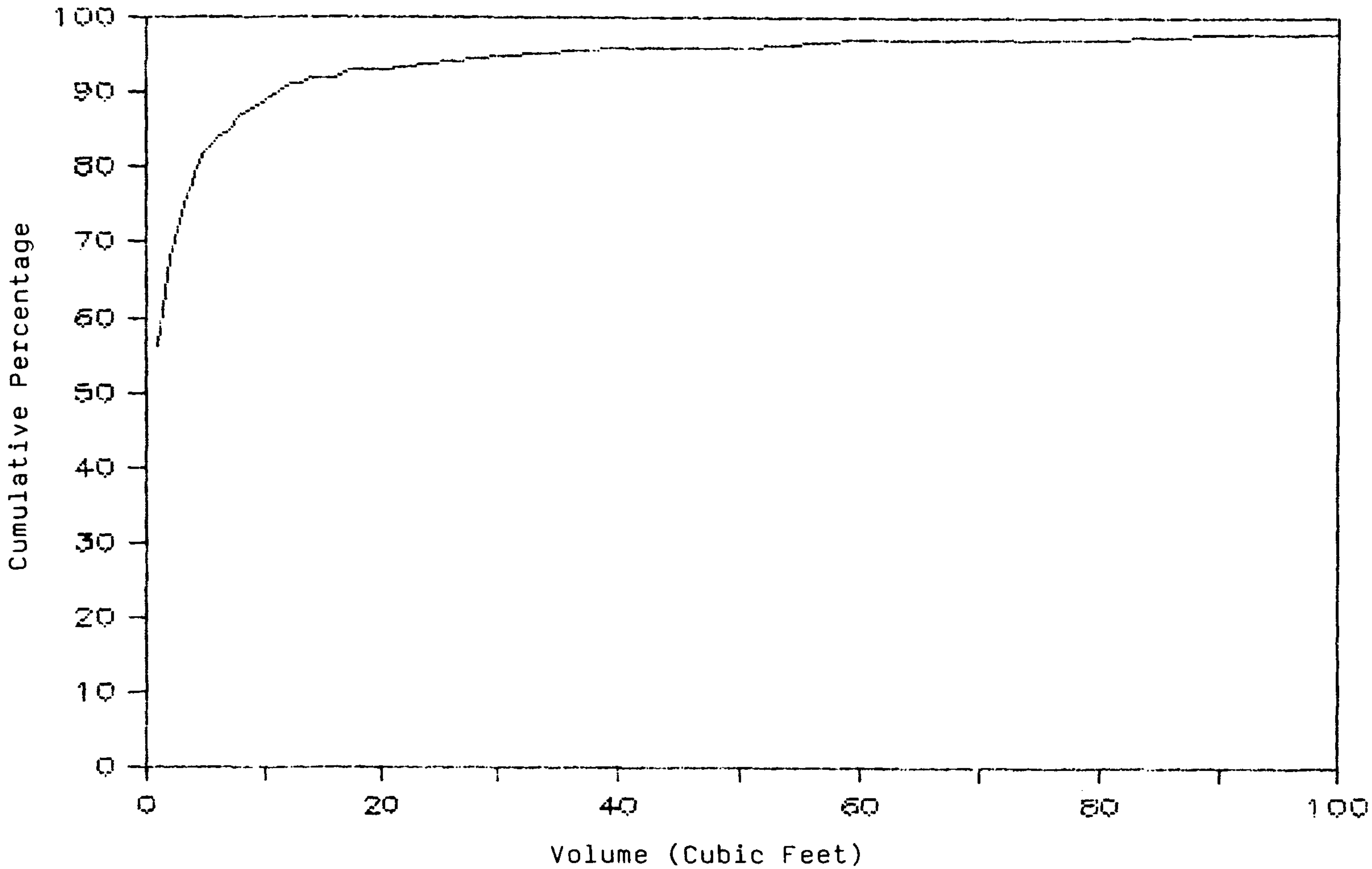

Fig 3.15 Cumulative Frequency by Volume
All MICAP Shipments 1-100 Cubic Feet

IV. Analysis of Cost Behavior

This chapter presents the background, methodology and findings for research objective #3:

> Determine the linearity of transportation costs for weight vs price for common carrier modes of transportation; first assuming distance to be fixed, and then assuming distance not to be a factor.

The characteristics of the data that were established in Chapter III give the decision maker an idea of the types of shipments that the transportation system must support. These characteristics are an important input to mode selection decisions. Combining with the shipment characteristics to dictate mode is cost of the shipment. Because of the competitive nature of the transportation business and the diversity of modes, a wide selection of options are available, and in transportation, as with other functions, the funds available to support those options are constrained. Therefore, the transportation manager must be able to accurately select the appropriate transportation mode; paying for premium, high-speed modes when time is critical, but settling for a more cost effective mode when the deadline is more flexible. The criteria developed for mode selection will impact on the total transportation budget and the amount of service that can be allocated to a common carrier.

Two separate areas of cost analysis are presented in this chapter, both of which are important to understanding the cost behavior and relative cost structures of various modes of transportation. The first area is understanding how cost varies as a function of weight given fixed distances. That is, assuming that distance is constant, is total line-haul cost as a function of shipment weight a linear, quadratic, exponential, or some other plot? Figure 4.1 shows some of the possible line-haul cost relationships. The second relationship analyzed is the relationship of distance to cost. In this case the objective is to determine the impact of assuming a standard cost in dollars/pound regardless of the distance to be shipped.

Importance of Cost Behavior

Relationship of Weight and Cost with Distance Fixed. In determining the transportation budget and requirements at the HQ USAF level, computer modeling can be of assistance. However, the modeler must be able to define the cost parameters in the model in the appropriate terms. Since cost can be expressed in numerous ways (dollars/pound, total line-haul cost, and dollars/ton-mile are three examples), the first requirement is to be explicit in the use and expression of cost in any analysis. In a strategic planning model with fixed origins and destinations, each path will represent a feasible means of transportation between two nodes. Associated with each transportation method will be the cost for using that mode expressed in cost/(unit weight shipped) expressed in dollars per pound. The decision maker can compare costs for a given weight, subject to the

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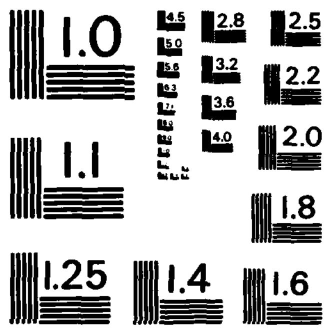
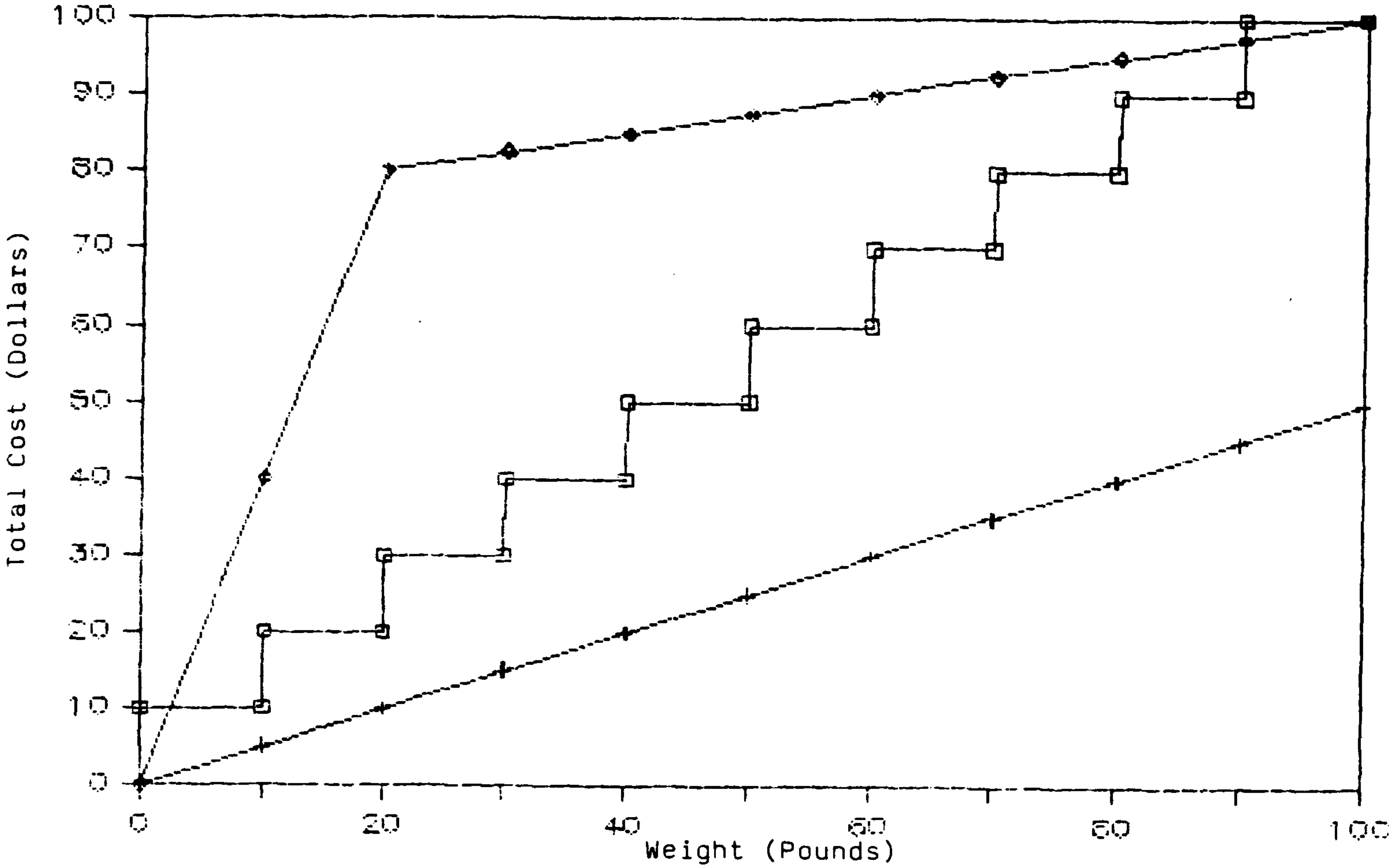


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



□ Stair Step + Constant Linear ◇ Two Linear Regions

Fig 4.1 Examples of Line-Haul Cost Behavior mode's capabilities and the shipment's required delivery date. However, using the single parameter, dollars/pound, implies that the cost function is completely linear over the entire range of weights. If cost is not linear over the entire range, then assuming a simple linear relationship will induce an error into the strategic planning model. That leads to the initial research question which was:

> On which modes of transportation is the function dollars/pound a constant linear relationship over the entire range of weight values?

If the modes of transportation are not linearly priced over the entire range of weight values, the modeler or decision maker has three courses of action. First, the input values can be reexpressed, so that the function more closely approximates linearity. A complete discussion of reexpression is included in Chapter III under exploratory data analysis. The second alternative is to analyze the affect of assuming linearity, even if there are regions that are not totally linear. If a region of a cost function is not linear, the impact may not be significant, since only a limited number of shipments will be affected. In this case assuming a linear cost function may not significantly degrade the final result.

The final course of action is to use model inputs that do not assume linear costs over the range of weights. Not assuming linearity will complicate the modeling effort, but if assuming linearity significantly degrades the accuracy of the model, this final course of action may be necessary.

For those modes where cost could not be expressed as a linear function with weight in pounds as in the independent variable and cost in dollars/pound as the dependent variable the following four questions were addressed:

1. Can a range of values be specified where behavior approximates a linear relationship?

2. Can the function be reexpressed in terms which creates a closer approximation to linearity?

3. If cost behavior is only partially linear, what percentage of the data set falls into the nonlinear range?

4. What error will be induced if linearity is assumed, even in non-linear regions?

Relationship of Weight and Cost with Distance Not Fixed. The second cost analysis was determining the affect of distance on the cost of transportation. The less complicated the inputs to a model, the easier a model will be to construct and interpret. If cost could be expressed in dollars/pound shipped for a given mode independent of the distance to be shipped, then the construction of a model would be greatly simplified. Therefore, the purpose of this analysis was to determine if cost could be assumed to be a constant, expressed in dollars per pound, regardless of the distance to be shipped. The following research question was addressed:

> For which modes of transportation can cost be assumed to be a constant figure expressed in dollars per pound, regardless of the distance to be shipped?

For those mode where cost was found not to be independent of distance, the following two questions were addressed:

1. What is the relationship of cost to distance for the transportation modes which do not display a constant dollars per pound relationship over all distances.

2. What error will be introduced if cost is assumed to be independent of distance?

Methodology for Determining Cost Behavior

The methodology for determining cost behavior and impact was a two step process consistent with the two sets of research questions listed in the previous section. The first analysis was determining if costs are linear for each of the available transportation modes. The second analysis will be determining if distance influences line-haul costs.

Relationship of Weight and Cost with Distance Fixed. Within each mode, a stratified, random sample of origin and destination pairs was used. The stratified sample was based upon distances from origin to destination to insure that the complete range of distances was included, since distance may influence the cost behavior. The behavior of cost may be different for shipments which travel a relatively long distance, when compared to those shipments which only move a short distance. For example, short haul costs may be linear, while long haul rates quadratic. Therefore, by not analyzing each, a faulty conclusion would be reached. For that reason, the behavior of cost was analyzed for both short and long distance shipments. The stratified sample covered a wide range of distances. The selection of origin and destination pairs was from samples grouped in 500 mile sets from 500 to 2500. In reality the only modes for which a random selection of origin and destination pairs was required was for less-than-truckload (LTL) shipments and LOGAIR shipments. The remaining common carrier modes are priced by zone, and the analysis was conducted on the behavior of the zones that cover 500 to 2500 mile shipments.

The cost behavior analysis, which included analyzing behavior for various distances and zones, was conducted using the same procedure for each mode. The starting point was a simple plot of weight (independent variable) against cost (dependent variable). Next, a regression was performed using the same independent and dependent variables. The previous section on exploratory data analysis was explicit on the background and necessary assumptions for regression. The third step was plotting weight in pounds (independent variable) against cost expressed in dollars per pound (dependent variable).

Each of the three inputs provides a unique insight into cost behavior. The graph of weight shipped to line-haul cost provided the initial visual plot for determining whether cost is linear over the complete range. A least squares line was superimposed on the plot to aid in determining if that mode and distance deviate significantly from a straight line. In addition to determining if the entire line appears straight, the decision maker can use the plot to determine if there are logical breakpoints for assuming ranges of linearity for different regions of the function.

The plot of weight versus total cost was the principal input for determining if ranges of linearity existed or whether reexpression of terms should be considered (research questions 1 and 2). If zones of linearity were identified, two separate plots were then constructed and analyzed to determine if separately the two plots became a closer approximation to a straight than the original single plot. If reexpression was a possibility, the new terms were plotted to determine if again a closer approximation was achieved. For one mode both reexpression and two separate zones of linearity were analyzed.

A second input for analyzing linearity is a simple, linear regression. The regression was used to determine how accurately weight can be used as a predictor of cost. The principle statistic used in this analysis was "r squared."

$$\text{r squared} = 1 - \frac{SSE}{SSY}$$

SSE is the sum square of the error terms, and SSY is the sum square of the dependent variable terms. A plot with all points forming a perfectly straight line would have an r squared of 1, since error terms, or deviation from the least squares line would be nonexistant. That means that for any value of the independent variable, the value of the dependent variable can be computed with perfect accuracy.

Therefore, the closer the value of r squared is to 1, the more accurate the least squares line as a predictor. For the purposes of this analysis, since the regression is deterministic and not probabilistic, the closer r squared is to a value of 1, the less deviation there is between the least squares line and the original plot. The conclusion that can be derived is that the closer r squared is to 1, the closer approximation to a straight line, and the less deviation in individual terms.

The least squares equation that was computed during the regression was used as a comparison to the plot of weight to total cost. If a linear cost relationship were assumed, then the least squares line values that would be derived from this least squares line would be the predicted costs for a given weight. Therefore, by seeing how this prediction compares to the actual, the two lines are plotted on the same graph. The decision maker can determine in which ranges actual and predicted costs differ significantly. If the two lines are exactly the same, then the least squares line is an exact predictor of cost.

The initial regression was over the entire range of possible values for the independent variable. From these results, the equation for the least squares line (superimposed on the first graph) and the residuals were obtained. The magnitude of the residual relative to the value of the total cost gave an indication of how much the original plot deviated from the least squares line. This input combined with the visual plot aided in determining if reexpression or zones of linearity should be considered.

For those modes in which zones of linearity were identified or the values reexpressed, regressions were recomputed and new r squared and residual terms produced. The new r squared terms and residual terms were compared to the original terms to determine if there was any improvement. In certain modes, the price for a one pound shipment was the same as a two pound shipment. The regression results improved if the one pound value for cost was eliminated. This step would not affect the overall accuracy of the model, since the modeler could assume that all shipments of two pounds or less would be the same price.

As with the original weight to cost plot, a least squares line was superimposed to allow a comparison between the actual and predicted costs. If the least squares line was a closer approximation to the actual cost line, then the reexpression, or smaller range of weights, improved the accuracy of any model which used cost expressed in a linear function as dollars/pound.

The final input, plotting weight (independent variable) vs cents/pound (dependent variable), showed the range over which the price per pound is linear. A horizontal line over the entire range demonstrated that the price/pound is constant over the entire range. Any other behavior indicated that cost behavior is not completely linear.

To determine any error induced by assuming linearity where that assumption is not entirely valid, error terms were compared to the actual values. The error term was derived using the least squares line, and comparing the predicted price from the least squares line with the actual price charged. For example, if the actual price for a ten pound shipment was $8.00, but the residual was 1.00, then the least squares line would predict a price of $9.00 for a ten pound shipment. That resulting ratio (error term/actual price) gives an estimation of the price error that would be induced if linearity would be assumed. In the previous example the error induced would be $1.00/$8.00=12.5%. To emphasize any impact, the percentage of shipments that would be affected by the estimation error were also included in the analysis.

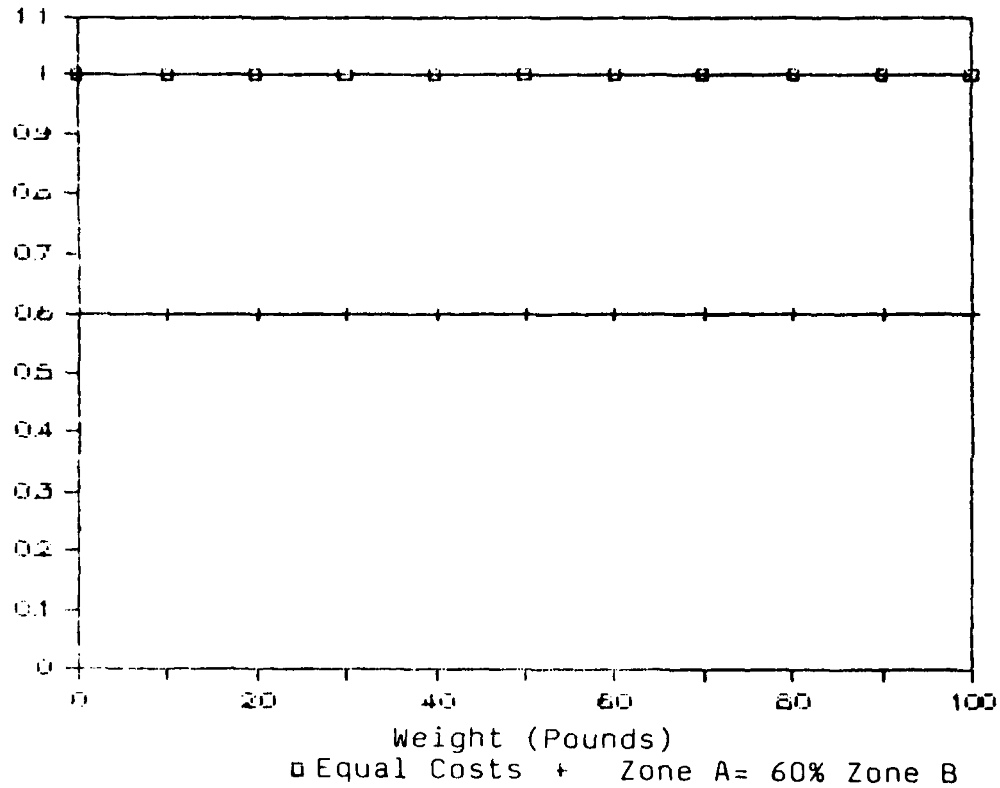
Relationship of Weight and Cost with Distance Not Fixed. To determine if line-haul costs were independent of distance, each mode was analyzed individually. Within each mode stratified samples based upon distance were used, as in the previous analysis. For the modes that had rates based upon zones, the zone charges were used in lieu of a stratified sample. For the modes that charged based upon specific origin and destination, the same origin and destination pairs were used as in the weight to total cost analysis.

The primary means of analysis was plotting weight (pounds) vs the ratio of the cost to ship to zone or destination A and the cost to ship to a zone or destination B.

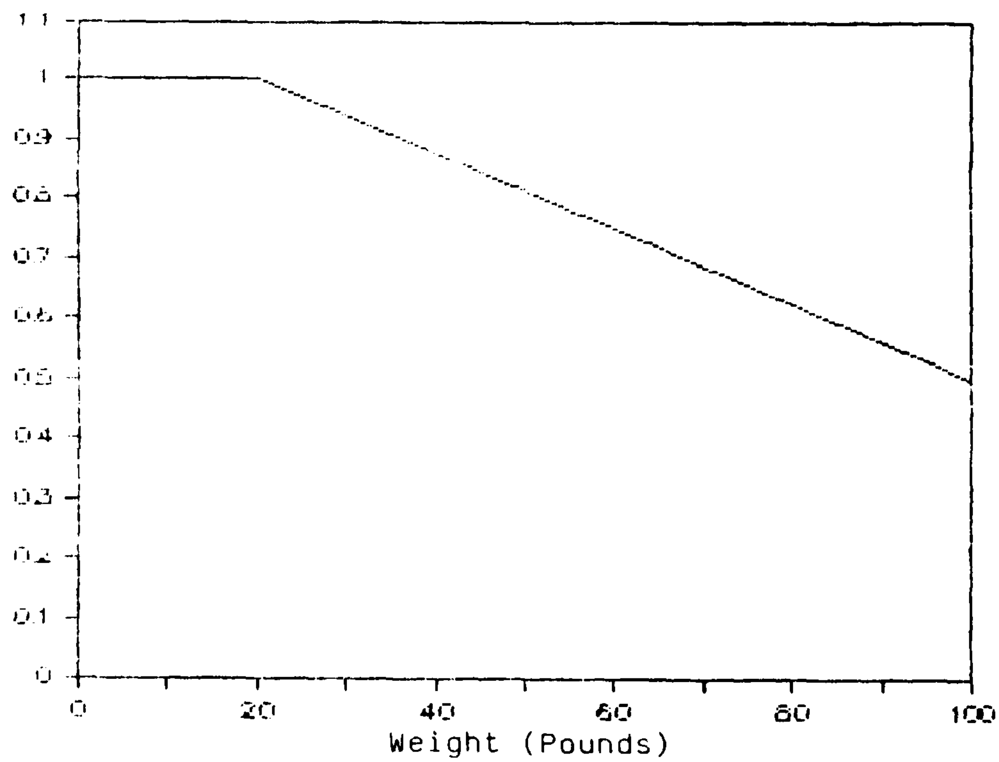
If cost could be assumed as a constant figure expressed in cents per pound and independent of distance, then the plot would be a horizontal line with a value of one. The horizontal line means that the total cost to ship to zone A divided by the total cost to ship to Zone B is a constant figure, regardless of distance to be shipped. For example, if the value were a constant .60, the total cost to ship to zone A is always 60% of the total cost to ship to zone B for any given weight. Therefore, if zone A is a closer destination, then the cost to ship a shorter distance is less than the cost to ship a longer distance. Therefore, the horizontal line indicates that the ratio of cost for two zones is constant; the value of that horizontal line indicates that one zone has a total cost consistently less than the second zone, and distance can be considered a factor in determining cost.

Figure 4.2 shows two possible relationships. The equal costs line would occur if the cost to ship to Zone A was identical to the cost to ship to Zone B, regardless of weight. The lower line would occur if the cost to ship to Zone A was a constant 60% of Zone B, regardless of weight.

A second possible relationship is that the cost to ship to zone A may be constant percentage of the cost to ship to Zone B for some weights, but that relationship changes as total weight changes. In this situation, total distance to be shipped would not influence cost in the first relationship, but would influence cost in the second. Figure 4.2



Example 1



Example 2

Fig 4.2 Examples of Cost Ratio Behavior

shows this example also. In this case the cost to ship to Zone A is identical to the cost to ship to Zone B for weights less than 20 pounds. However, as weight increases the cost to ship to Zone B is increasing at a decreasing rate, relative to the cost to ship to Zone A. By 100 pounds, the cost to ship to Zone A is only half the cost to ship to Zone B. In this instance, if the assumption had been made that distance does not impact cost, either Zone A cost would be 100% too high, or Zone B 50% too low for weights greater than 20 pounds.

Analyzing the cost behavior provided the information necessary for establishing if distance to be shipped impacted total cost.

Cost Behavior Findings

The following commercial modes of transportation were analyzed:

1. First class mail (US Postal Service (USPS))
2. Surface parcel post (USPS)
3. Federal Express
4. United Parcel Service (UPS)
5. Express mail two day delivery (USPS)
6. Express mail next day delivery (USPS)
7. Less than Truckload Shipments (LTL)

Relationship of Weight and Cost with Distance Fixed. The analysis produced two general findings. First, each mode has individual cost characteristics, and therefore, each must be addressed individually and not as a single group which would encompass all common carriers. The second general finding was that cost behavior within each mode was not a function of distance. Although total cost increased as distance increased, the shape of the cost function based upon weight did not vary as distance increase. That is, those modes that displayed linear relationships for the shorter distances, likewise displayed linear relationships for the longer distances. The modes which were not linear for the shorter distances were nonlinear in the same manner for the longer distances.

Table 4.1 contains a comparison of r squared terms for each of the seven modes and five different zones based upon distance.

Since each mode had individual characteristics, the conclusions will be presented in separate subsections based

Table 4.1

R squared Terms by Zone and Mode

ZONE MODE	4	5	6	7	8
FIRST CLASS MAIL	.99997	.99997	.99996	.99995	.99995
SURFACE PARCEL	.99347	.97307	.97262	.97362	.97261
UNITED PARCEL	.93838	.92358	.91424	.90665	.93676
EXP MAIL #1	.99998	.99276	.99997	.99996	.99996
EXP MAIL #2	.99992	.99991	.99998	.99998	.99994
LTL	.99571	.98427	.99756	.99438	.99743

upon mode. As outlined in the methodology section, the three areas of analysis in each section will be:

1. Plotting of weight vs total cost (in dollars) with least squares line superimposed.

2. Discussion of results from the regression of weight to cost.

3. Plotting of weight to dollars/pound.

A summary of the regression results are found in Tables 4.2, 4.3 and the Appendix. Table 4.2 has a summary of all the r squared terms for the regressions that were computed. This table shows how reexpressing the cost function or using two zones of linearity enable the decision maker to assume that line haul cost is linear as a function of weight.

Table 4.3 has the largest residual value for each of the common carrier cost functions for which a regression was computed. The weight (in pounds) at which that the largest residual occurred is also contained in the table. The figures are discussed in each common carrier section, and are presented in the table for comparison. For the purposes of this analysis the largest value is actually the value with the largest absolute value, since a negative residual will affect the accuracy as much as a positive error. The three regressions computed using cost=cost squared were omitted, because that residual term is not meaningful.

The Appendix contains a table with the least squares equations that are superimposed on the plots of weight in pounds against line haul cost in dollars.

Table 4.2

R squared Terms for Ranges Used in Cost Behavior Analysis

MODE	RANGE OF WEIGHTS (LBS)	REEXPRESSION	R SQUARED
FIRST CLASS MAIL (4)	1-70	N	.99974
USPS SURF(4)	1-70	N	.93838
USPS SURF(4)	2-20	N	.98139
USPS SURF(4)	21-70	N	.99112
USPS SURF(4)	1-70	COST=COST**2	.99284
USPS SURF(4)	2-20	COST=COST**2	.99790
USPS SURF(4)	21-70	COST=COST**2	.99894
FED EXPRESS	1-150	N	.98647
FED EXPRESS	2-10	N	.98812
FED EXPRESS	11-150	N	1.00000
UPS (4)	1-70	N	.97347
UPS (4)	1-50	N	.99999
UPS (4)	51-70	N	.99988
EXP MAIL 1 (4)	1-70	N	.99998
LTL(SAC-BOS)	1-10,000	N	.99743
LTL(SAC-BOS)	1-5,000	N	.99698
LTL(SAC-BOS)	5000-10,000	N	1.00000

(4) IS TO ZONE 4
SAC-BOS IS SACRAMENTO TO BOSTON
COST**2 IS COST SQUARED

Table 4.3

Largest Resulting Error Terms for Ranges Used in Cost Behavior Analysis

MODE	RANGE OF WEIGHTS (LBS)	REEXPRESSION	LARGEST RESIDUAL	WEIGHT(LBS) AT WHICH RESIDUAL OCCURRED
FIRST CLASS MAIL (4)	1-70	N	-33.28	2
USPS SURF(4)	1-70	N	-115.26	2
USPS SURF(4)	2-20	N	-22.58	20
USPS SURF(4)	21-70	N	-19.89	21
FED EXPRESS	1-100	N	-1149.75	2
FED EXPRESS	2-10	N	-101.75	2
FED EXPRESS	11-100	N	0	N/A
UPS (4)	1-70	N	-123.12	70
UPS (4)	1-50	N	-.04	45
UPS (4)	51-70	N	-.55	51
EXP MAIL 1 (4)	1-70	N	-37.08	2
LTL(SAC-BOS)	1-10,000	N	49.35	4400
LTL(SAC-BOS)	1-5000	N	20.80	1700
LTL(SAC-BOS)	5000-10,000	N	0	N/A

(4) IS TO ZONE 4
SAC-BOS IS SACRAMENTO TO BOSTON
NOTE: LARGEST RESIDUAL COLUMN IS THE LARGEST ABSOLUTE VALUE

All cost data was compiled from the 1985 Transportation Automated Routing System (TARS) guide for the Sacramento Air Logistics Center (41). The Sacramento guide was compared to and determined to be identical to the cost data in the 1985 TARS guide for the Oklahoma City Air Logistics Center (40). The costs are the common carrier costs, and do not include services for which there would be an additional charge.

First Class Mail.

Plot of Weight vs Cost. Figure 4.3 shows that weight vs cost for first class mail closely approximates a straight line. The superimposed least squares line confirms that analysis.

Regression. When a regression was computed with weight as the independent variable and cost as the dependent, r squared = .99974. The largest residual term occurred at two pounds.

If the regression is computed without including the one pound value and associated cost the accuracy of the regression improves. Since the price for shipping one pound is the same as two pounds, all one and two pound shipments could be combined without degrading accuracy. A way of analyzing the improved accuracy from eliminating the one pound value is to view the residuals. The largest residual as 34.2 for 1-70, but only -9.7 for 2-70 pounds; a 72% improvement.

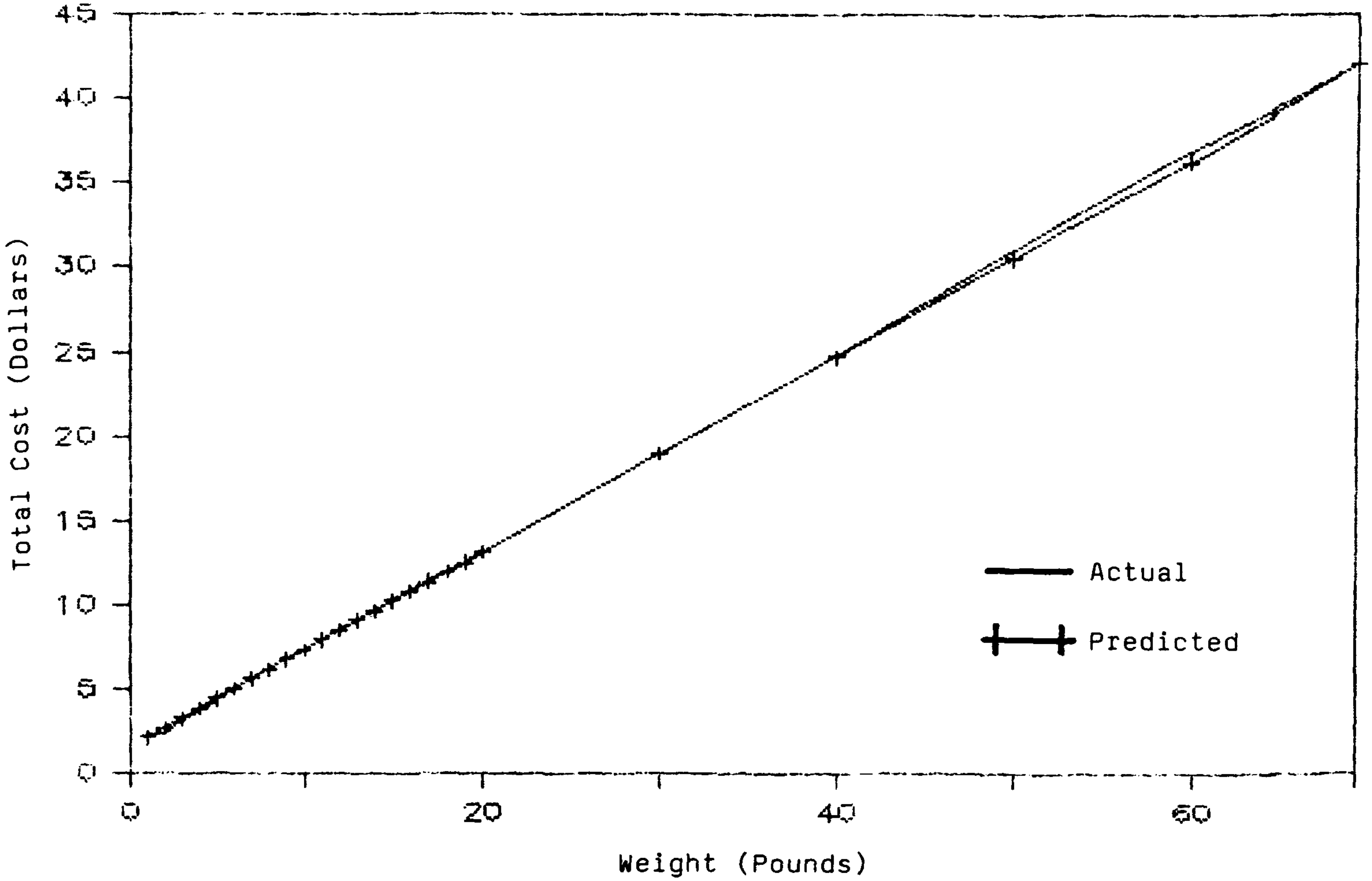


Fig 4.3 Comparison of Actual and Predicted Costs
First Class Mail 1-70 Pounds

Weight vs Price per Pound. The plot of weight versus price/pound (Figure 4.4) demonstrates how cost/pound decreases significantly until 11 pounds is reached. At that point the plot remains fairly horizontal. This graph is just a second method of viewing the previous results.

Conclusion. For first class mail shipments the total line-haul cost varies proportionately with respect to shipment weight. The regression results show only small residual values. Therefore, cost can be assumed as linear, especially from 10-70 pounds. Caution must be used for weights 10 pounds and below, because as Figure 4.5 reveals price/pound is not constant in that range. Since 47% of all shipments are 10 pounds or less, a significant error would occur if a single value (in dollars/pound) were assumed for all shipments 10 pounds or less.

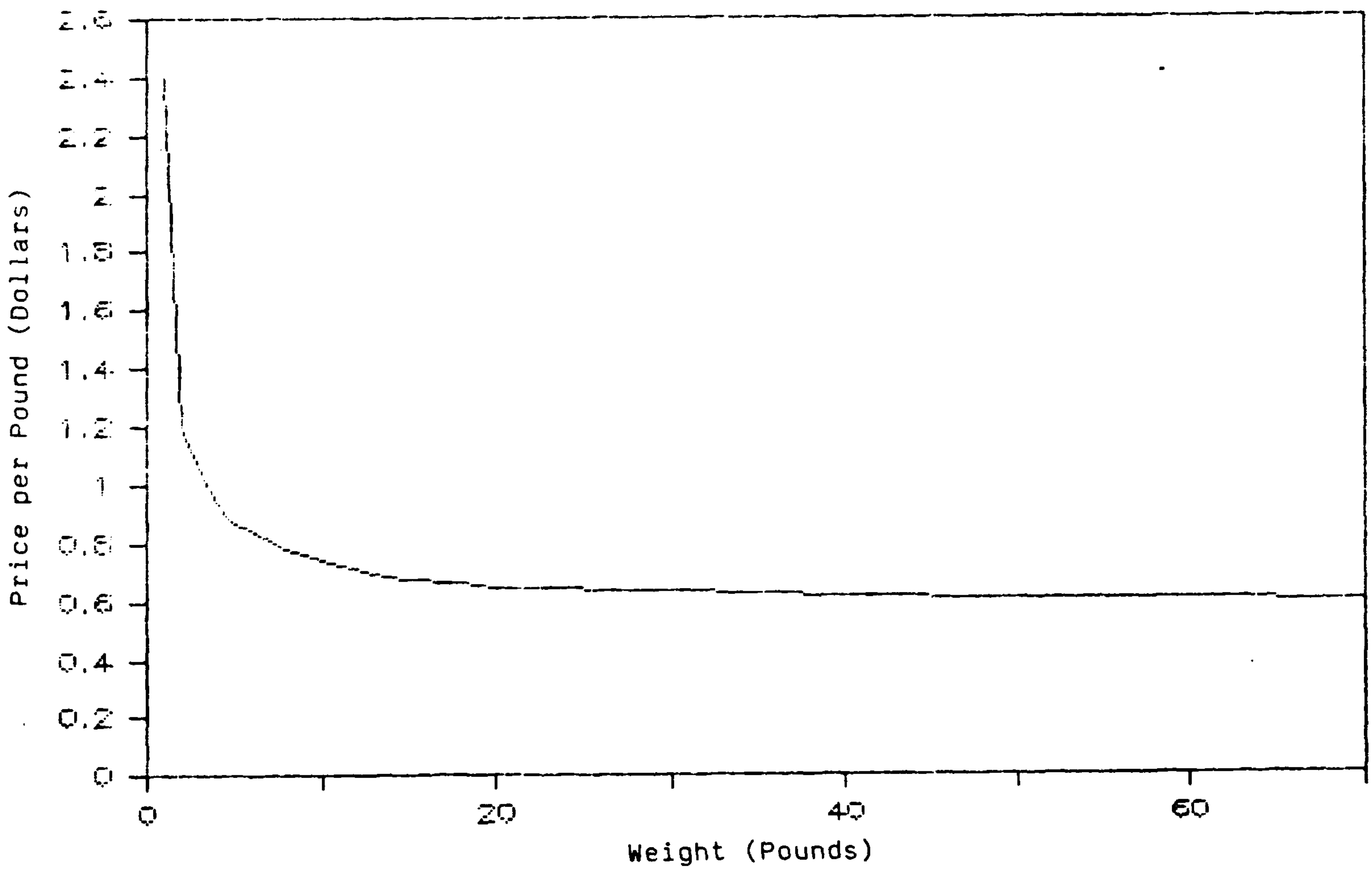


Fig 4.4 Price per Pound for First Class Mail

Surface Parcel Post.

Weight vs Cost. The plot of weight vs cost (Figure 4.5), with the least squares line superimposed, demonstrates that the relationship is not linear. However, the relationship closely approximates a linear relationship if two separate regions are designated. Breaking the function at 20 pounds will create two approximately linear relationships (Figures 4.6 and 4.7). Using the techniques presented in exploratory data analysis (Chapter III), the variables were reexpressed to determine if a closer approximation to linearity was possible. Figure 4.8 shows the plot of 1-70 pounds vs the cost squared. Figures 4.9 and 4.10 combine the two previous analyses (Figures 4.6 and Figure 4.7). The weights are separated into two ranges (1-20 and 21-70) and the ranges are individually plotted against the dependent variable reexpressed as cost squared.

Regression. A regression of weight vs cost confirms the initial indications above. Table 4.2 shows the r squared value for various regressions computed with weight as the independent variable, and either cost or cost squared as the dependent variable. Table 4.4 shows the overall improvement for cost accuracy when two zones are used and cost is squared as compared to not modifying the function at all. Simply reexpressing cost as cost squared has improved the r squared term from .93838 to .99284, even if the weights are not separated into two different ranges. The

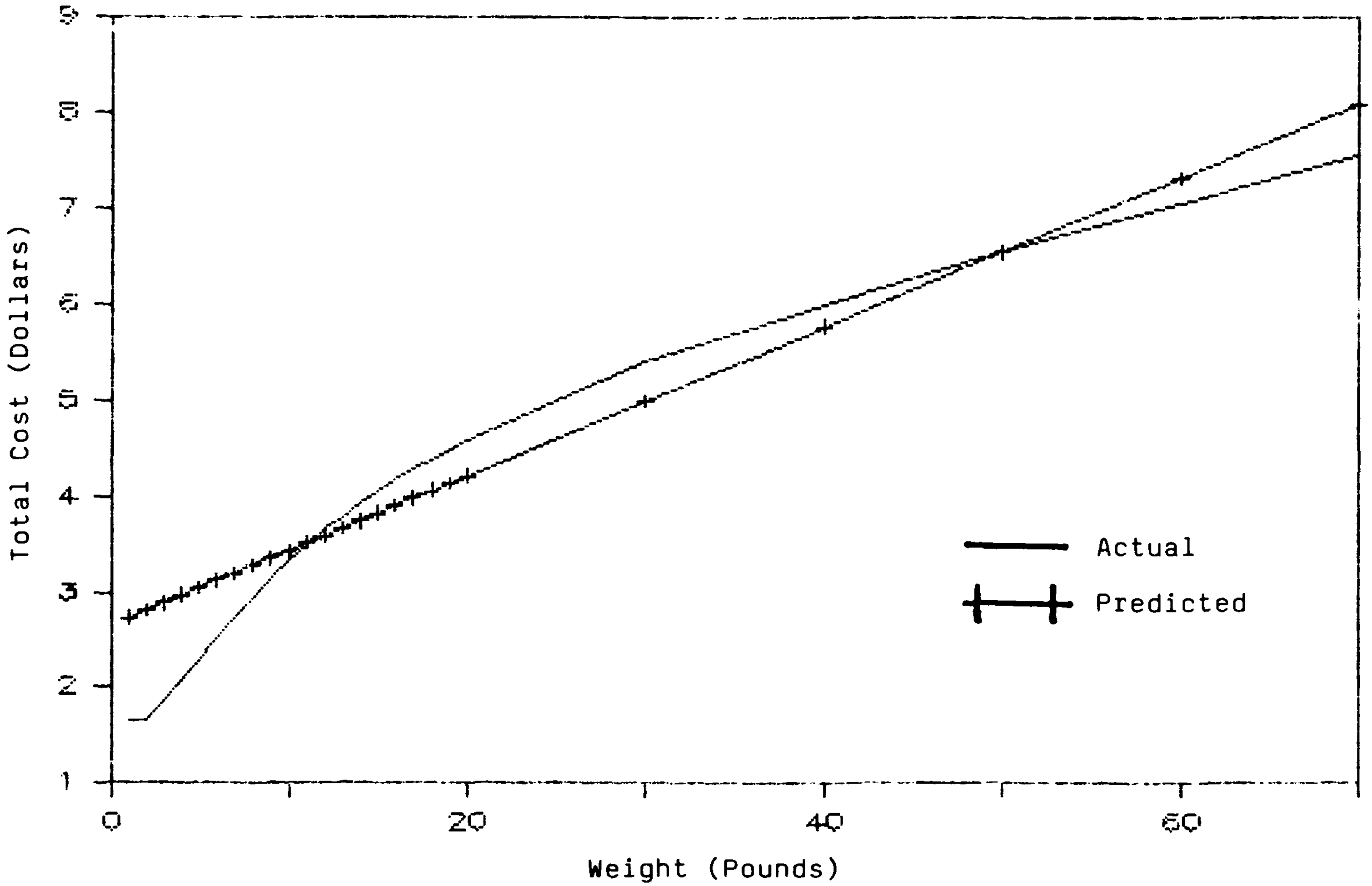


Fig 4.5 Comparison of Actual and Predicted Costs
Surface Parcel Post 1-70 Pounds

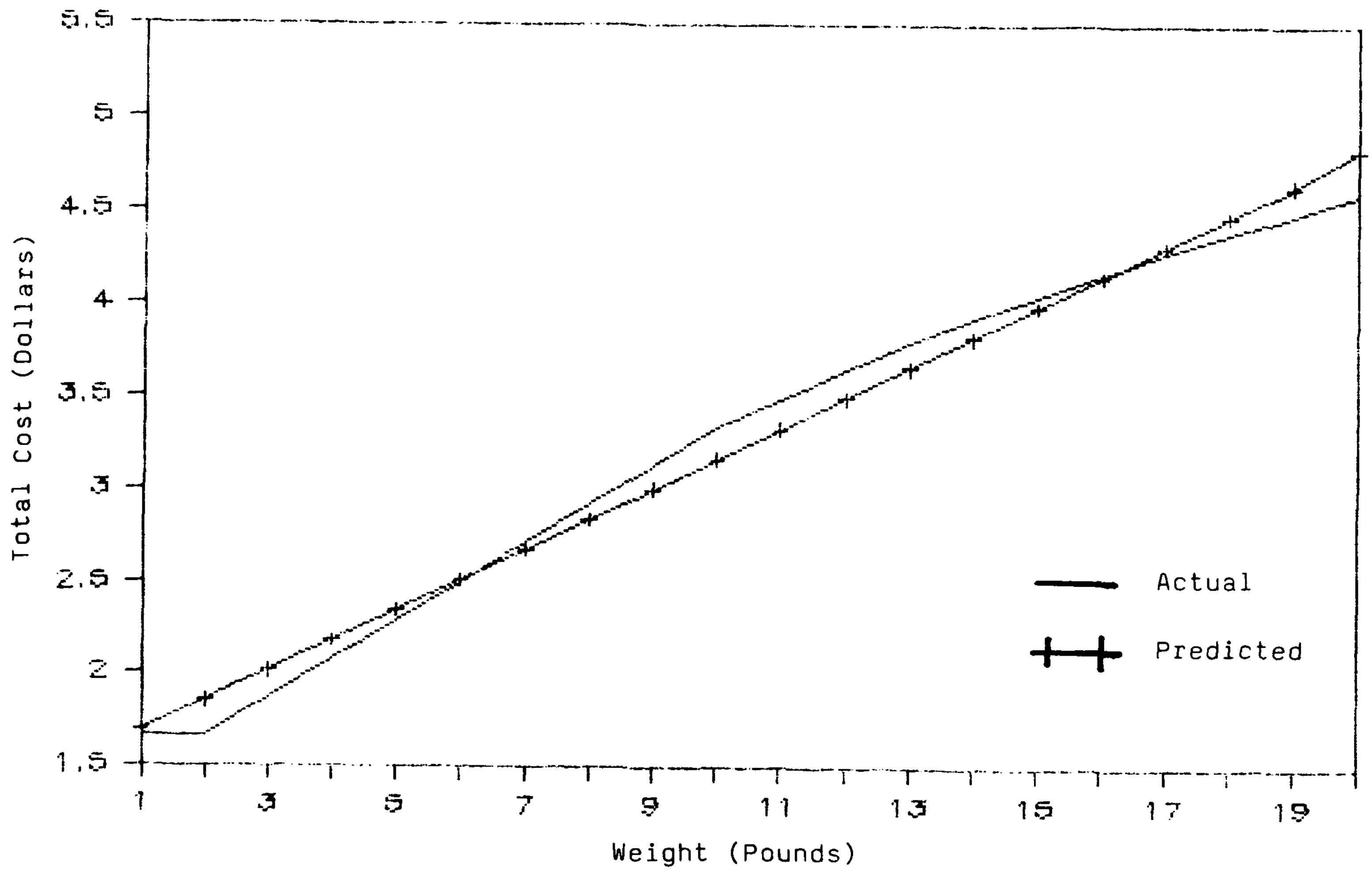


Fig 4.6 Comparison of Actual and Predicted Costs
Surface Parcel Post 1-20 Pounds

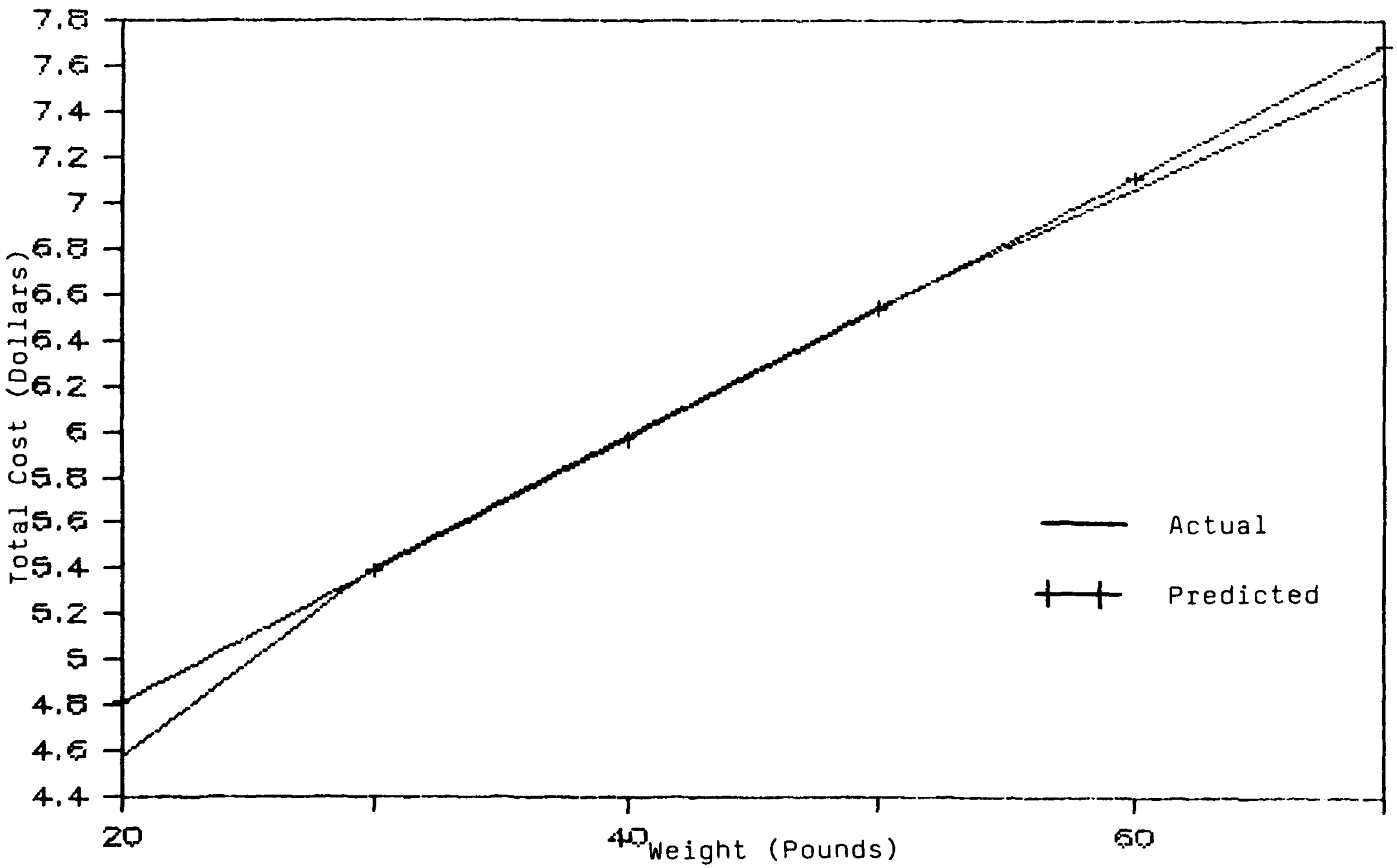


Fig 4.7 Comparison of Actual and Predicted Costs
Surface Parcel Post 20-70 Pounds

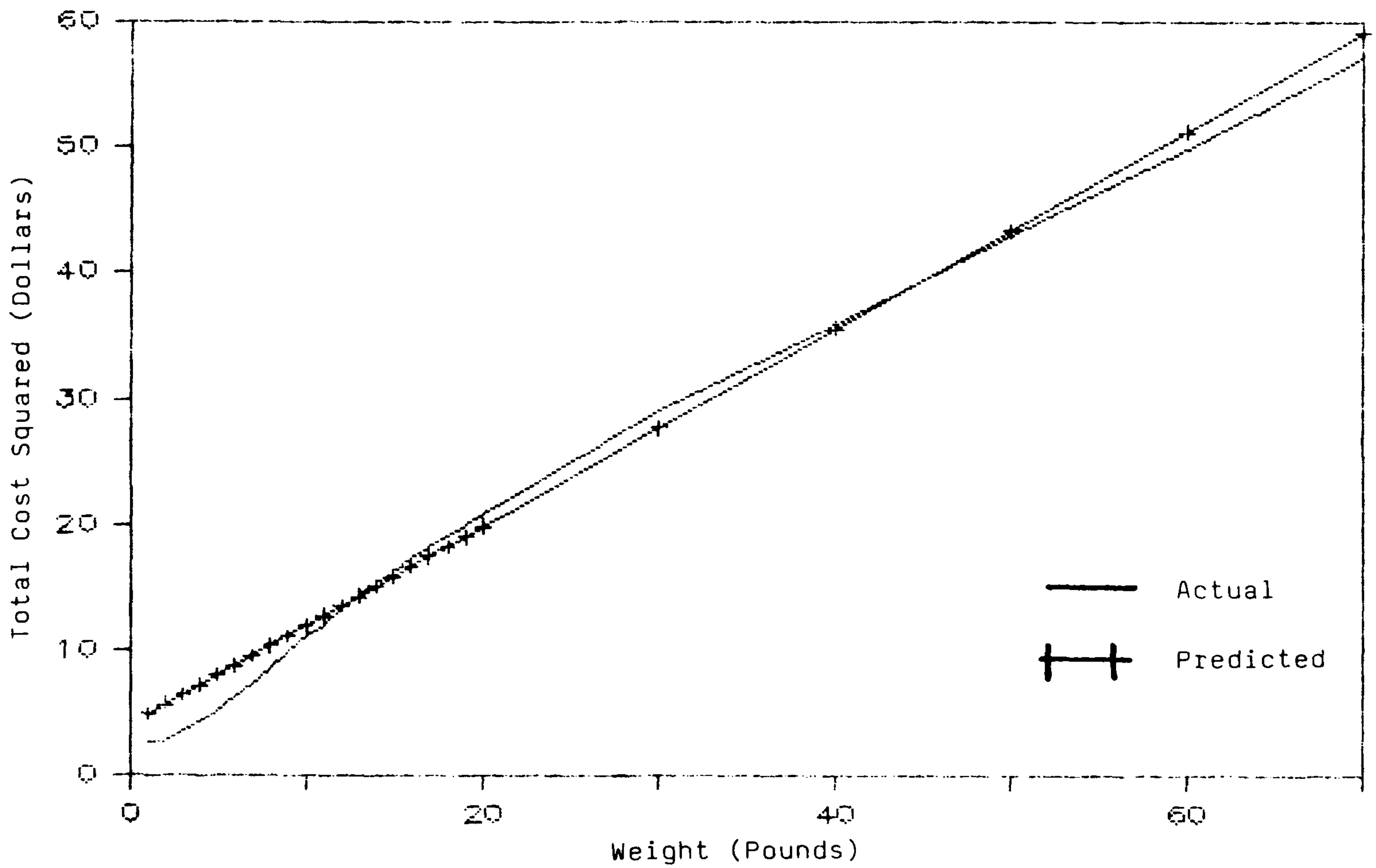


Fig 4.8 Comparison of Actual and Predicted Costs
Surface Parcel Post 1-70 Pounds

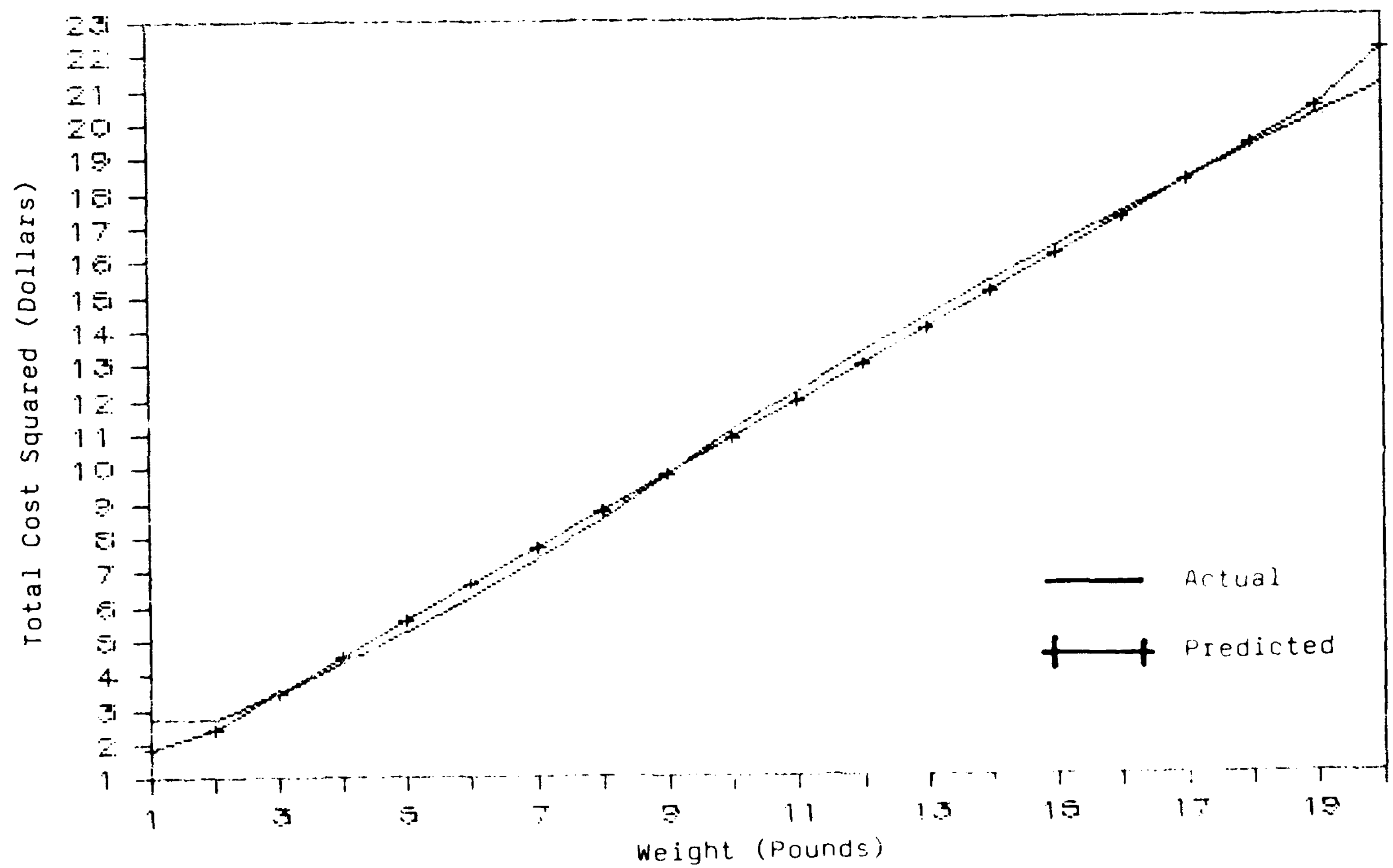


Fig 4.9 Comparison of Actual and Predicted Costs
Surface Parcel Post 1-20 Pounds

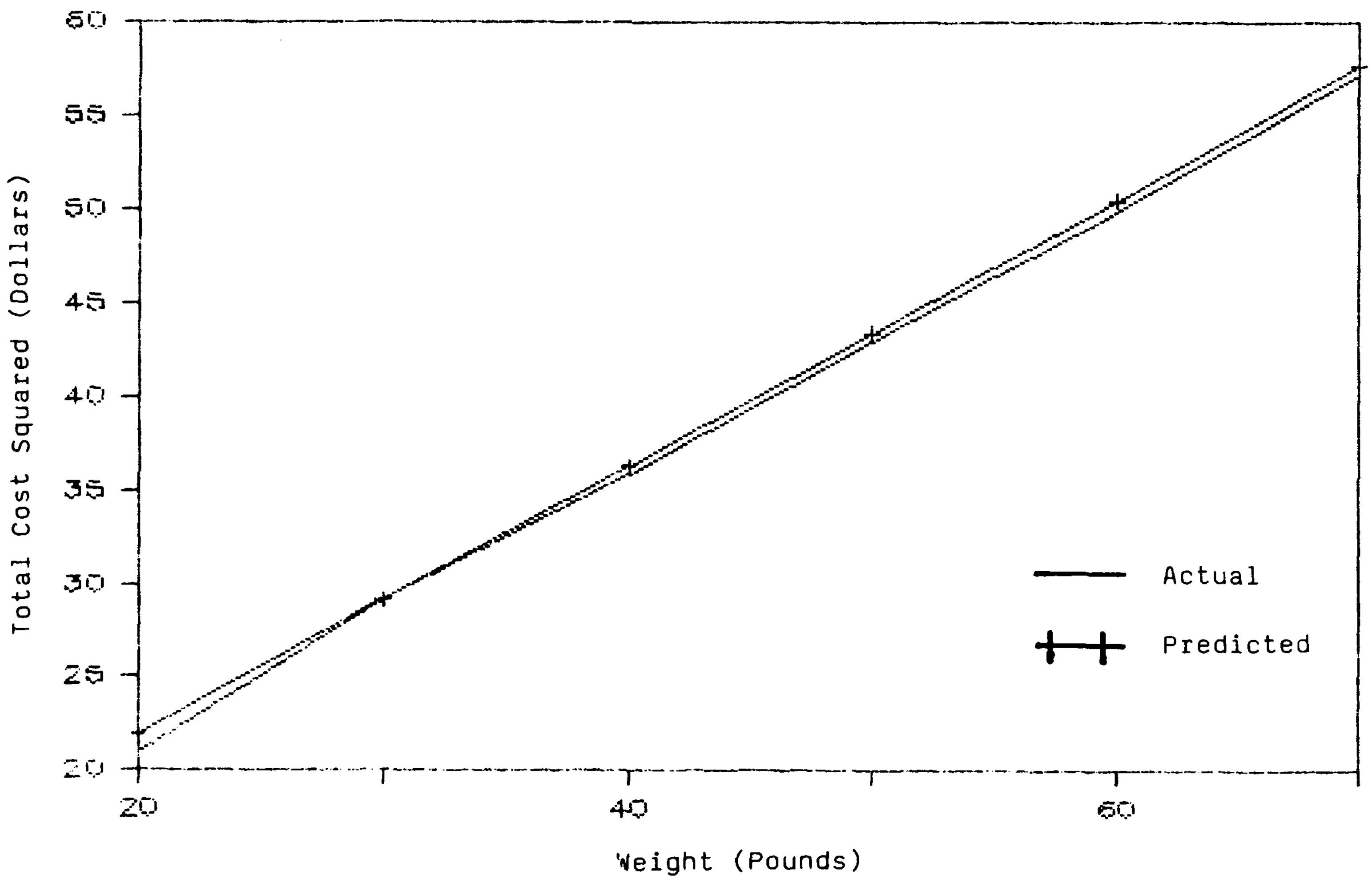


Fig 4.10 Comparison of Actual and Predicted Costs
Surface Parcel Post 20-70 Pounds

Table 4.4

Improvement in Residuals for Surface Parcel Post

Range	R squared	New Residual	Improvement
1-20	.99790	1.92	83%
20-70	.99893	1.87	67%

largest residual was decreased by 83% when two separate ranges were considered. Even though the initial relationship was not linear, taking the two simple steps, creating two ranges and reexpressing cost, has created a close approximation.

<u>Weight vs Price per Pound</u> Similar to first class mail, the cost expressed as dollars/pound is relatively constant for values above 11 pounds (Figure 4.11).

<u>Conclusion.</u> Surface parcel post is not a linear relationship. If a model wishes to incorporate surface parcel post as a linear relationship, then the cost in dollars/pound should be expressed in two different figures; one figure for each linear region. Also the cost should be incorporated as the value cost squared.

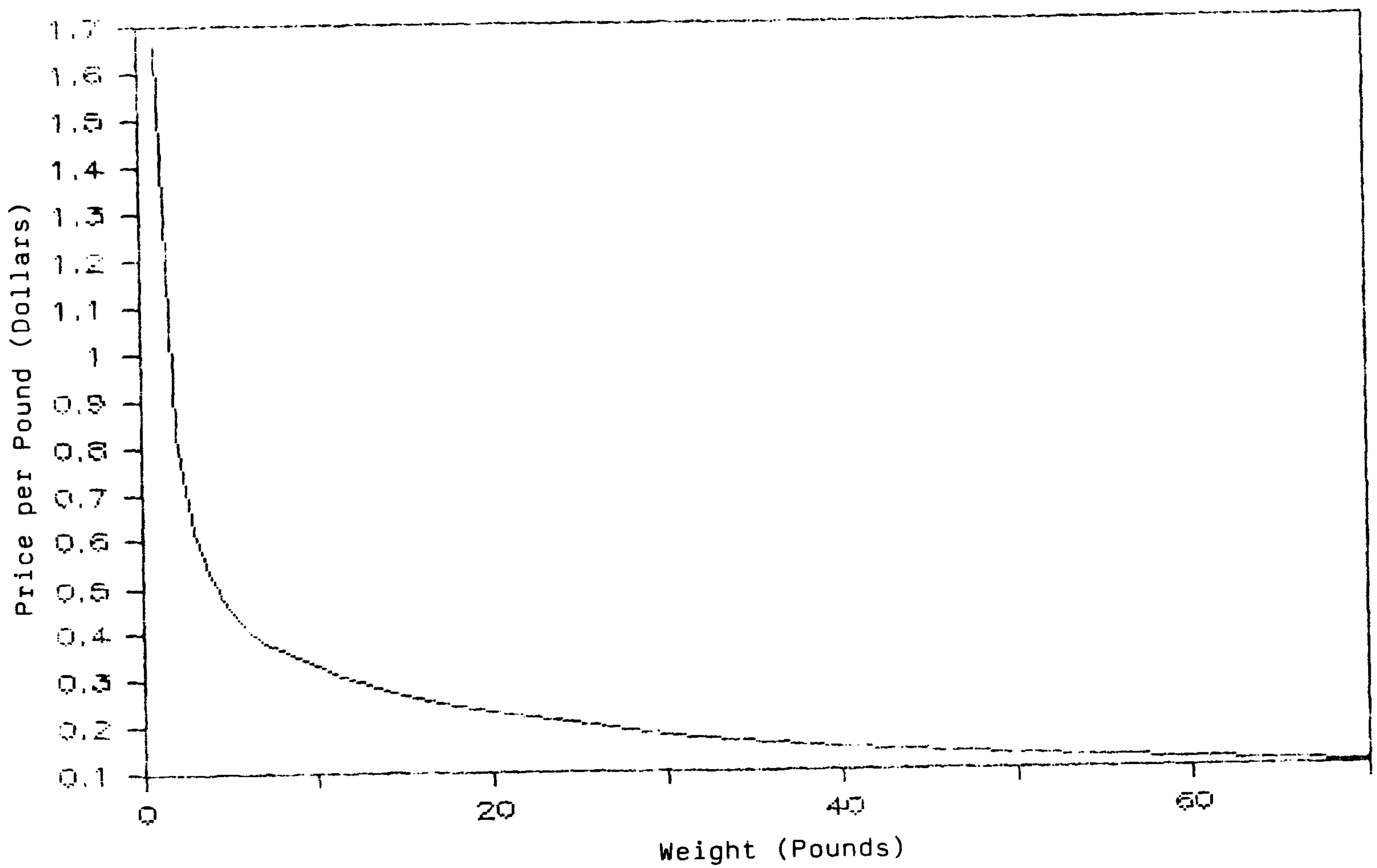


Fig 4.11 Price per Pound for Surface Parcel Post

Federal Express.

Weight vs Cost. The plot of weight vs cost (Figure 4.12) for Federal Express is similar to the first class mail graph. That is, two distinct linear regions emerge. Weights from 1-10 pounds comprise the initial linear region and 11-150 the second. Comparing the graph of weights 1-150 with the least squares line shows that assuming a single linear relationship would not be satisfactory. Figures 4.13 and 4.14 show the plots for the two separate ranges, and viewed individually closely resemble linear relationships.

Regression. A regression of the total range of weights (1-150 pounds) against costs produces an r squared of .98641 and creates large residuals; the maximum being 11.49. However, computing two separate regressions, ranges 1-10 and 11-150, improved the r squared value and decreases the residuals (Table 4.5).

Table 4.5

Improvement in Residuals for Federal Express

Range	R squared	Max Residual	Decrease in Residual
1-10	.9880	1.01	92.3%
11-150	1.0000	0	100.0%

Weight vs Price per Pound. The plots are similar to other modes, initially decreasing rapidly and then only modest decreases for the remainder of the values.
Figure 4.15 shows that for Federal Express, cost expressed in dollars/pound decreases rapidly to 20 pounds, from $14.00

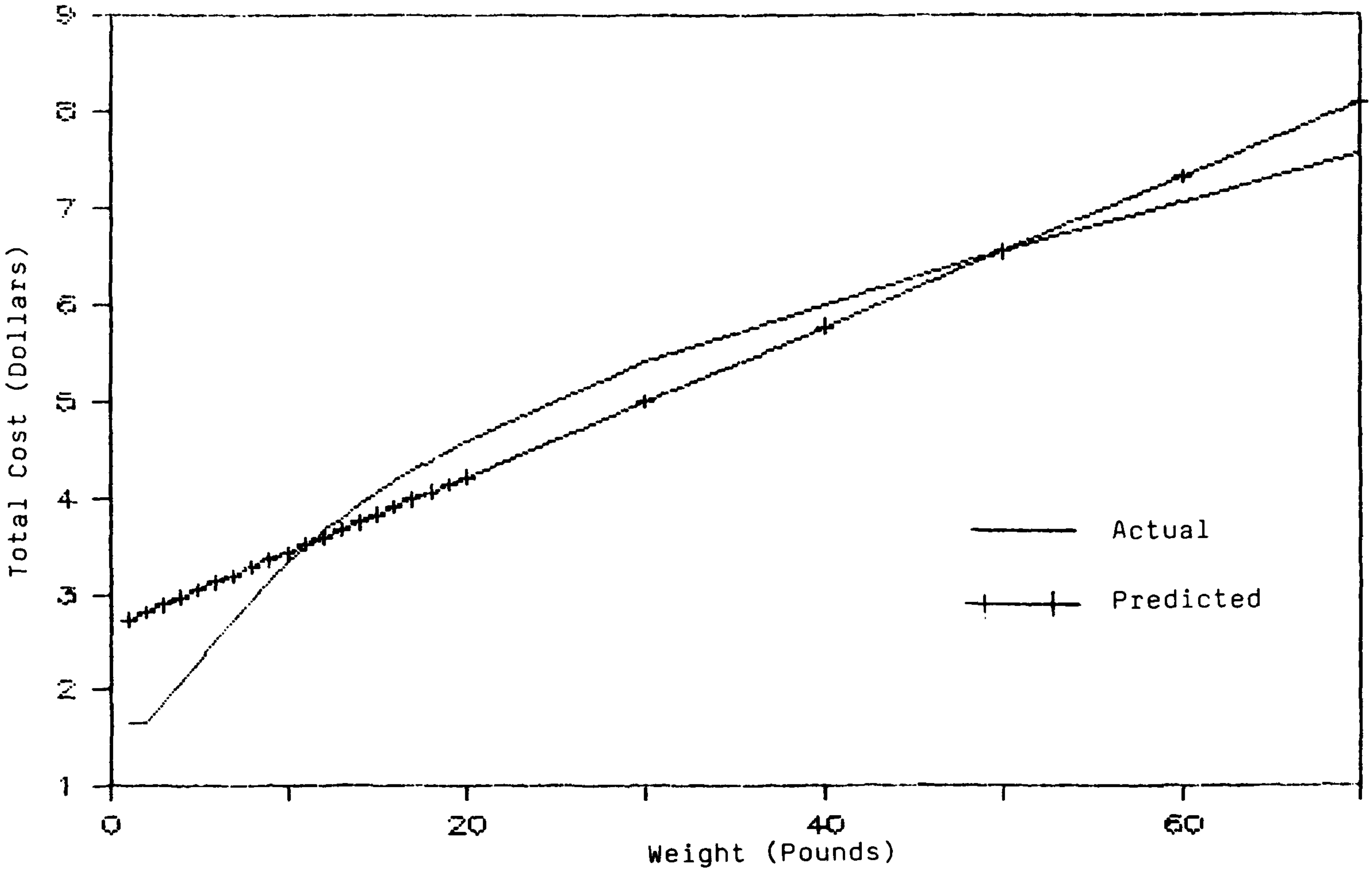


Fig 4.12 Comparison of Actual and Predicted Costs
Federal Express 1-150 Pounds

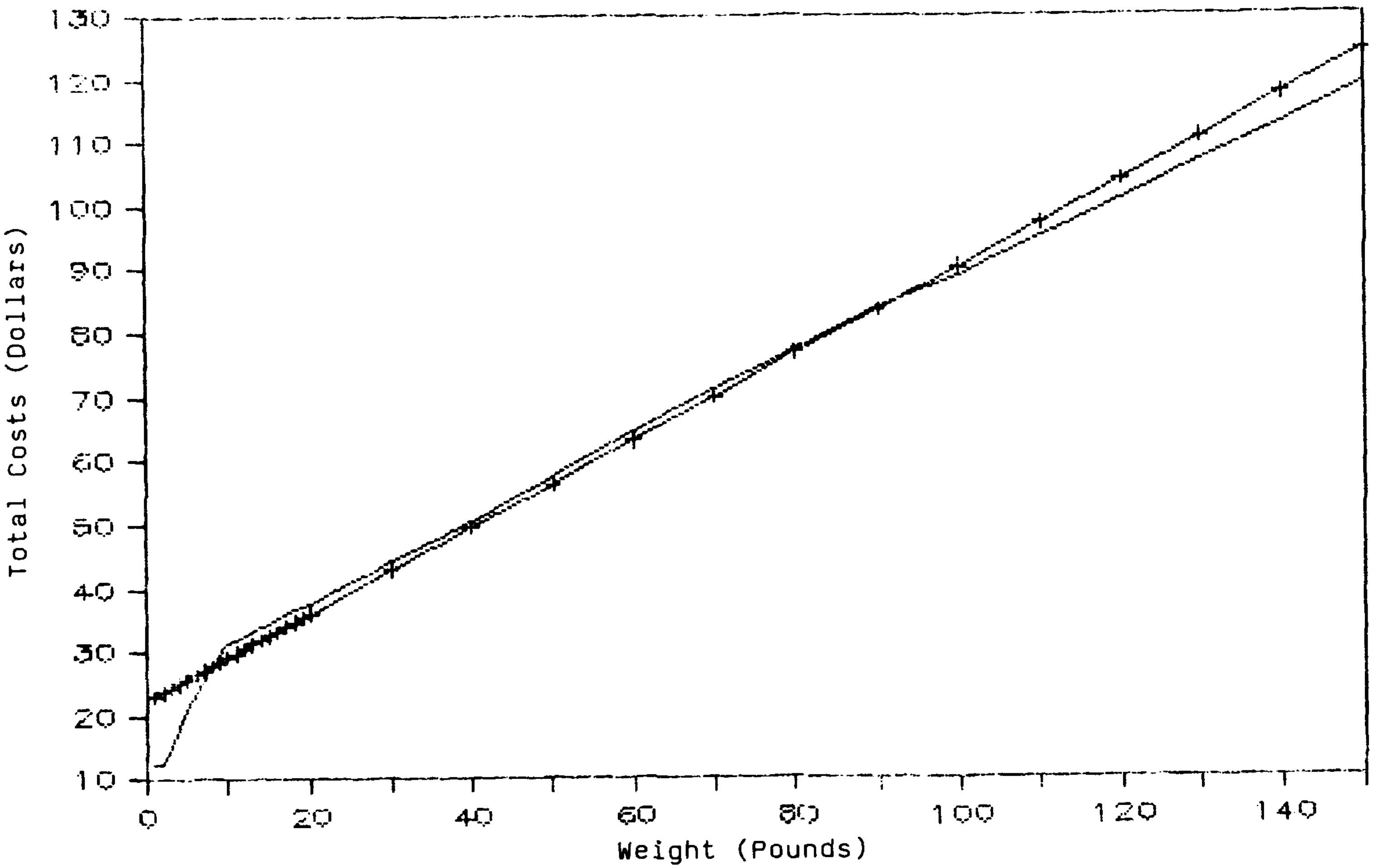


Fig 4.12 Comparison of Actual and Predicted Costs
Federal Express 1-150 Pounds

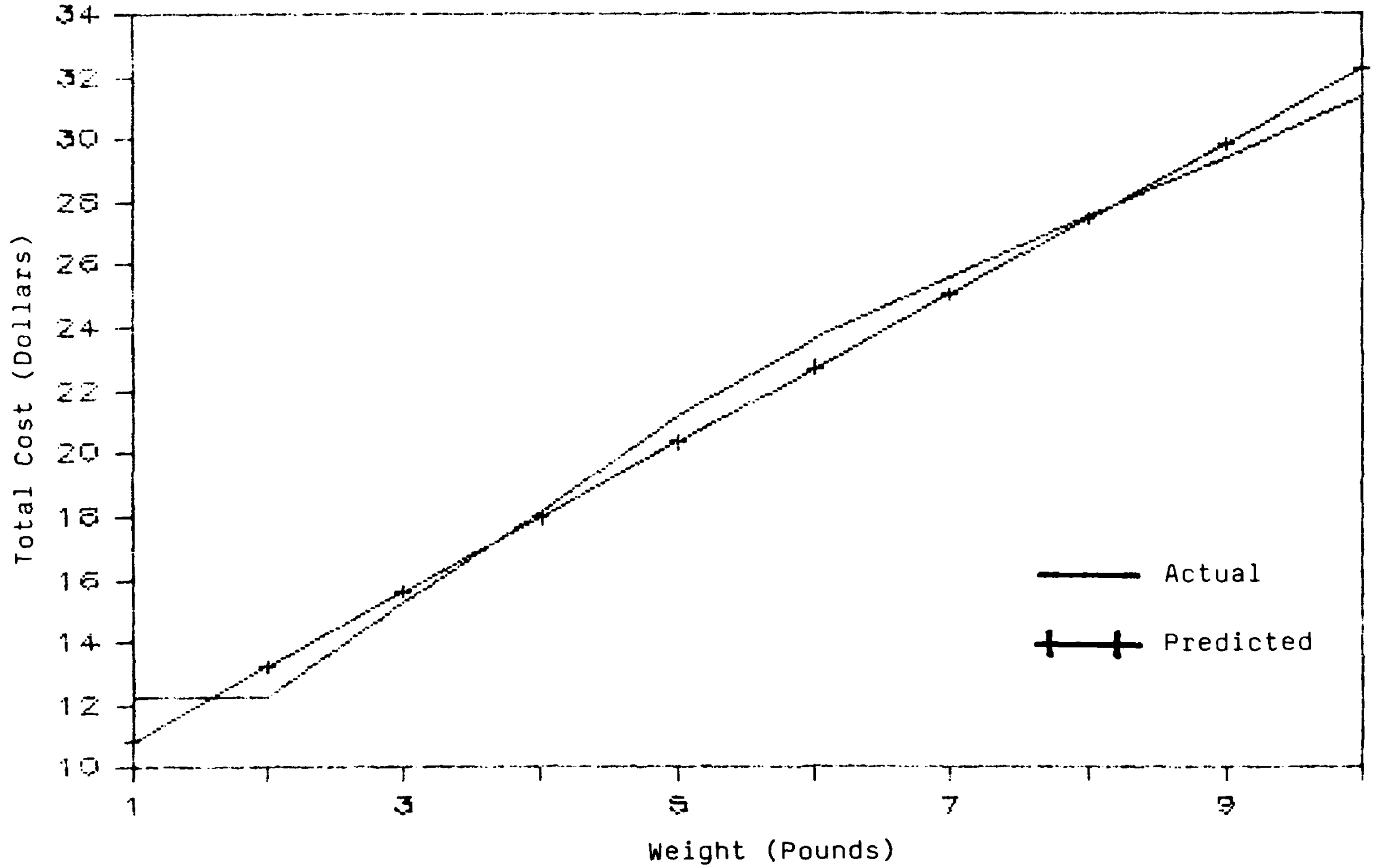


Fig 4.13 Comparison of Actual and Predicted Costs
Federal Express 1-10 Pounds

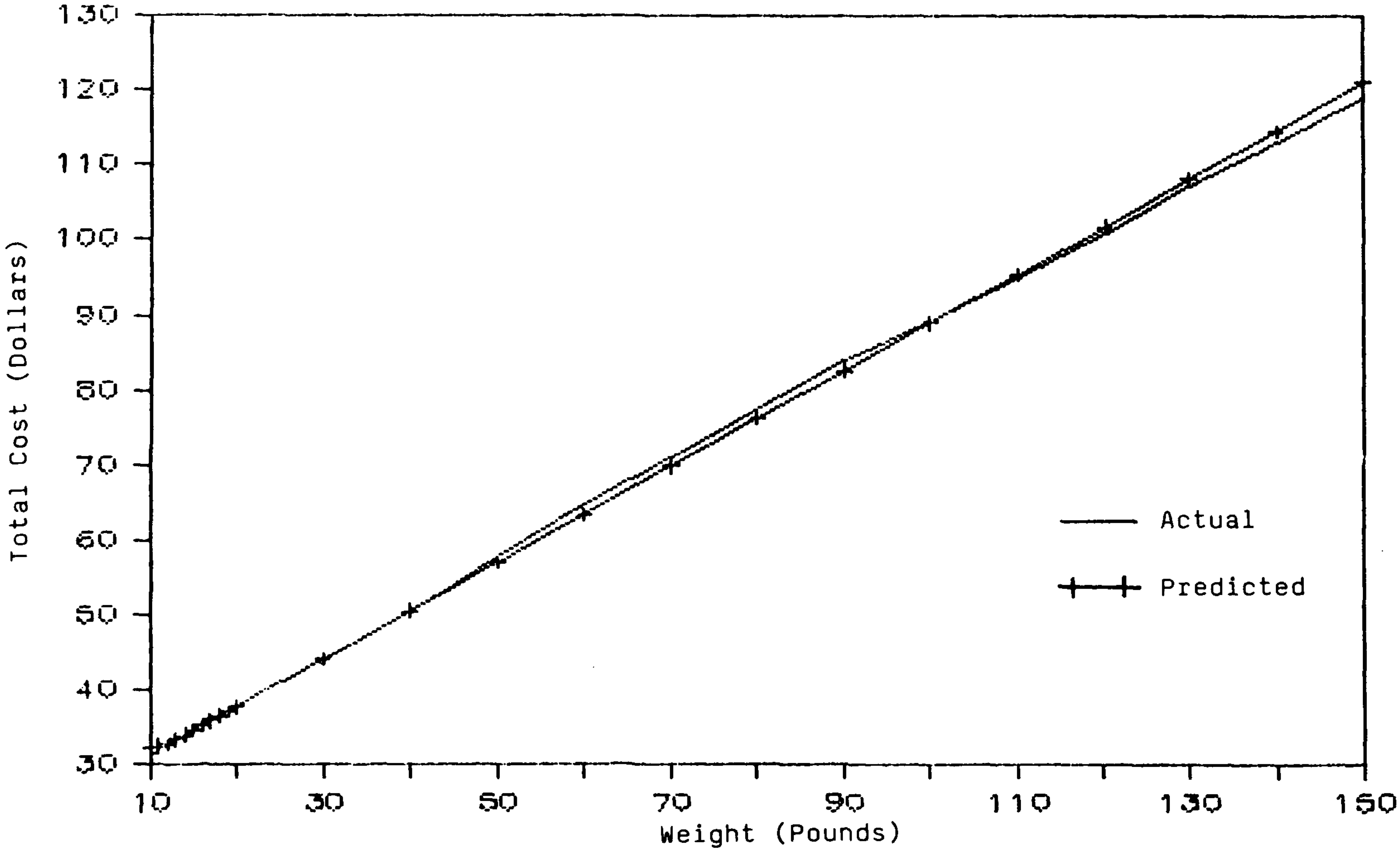


Fig 4.14 Comparison of Actual and Predicted Costs
Federal Express 10-150 Pounds

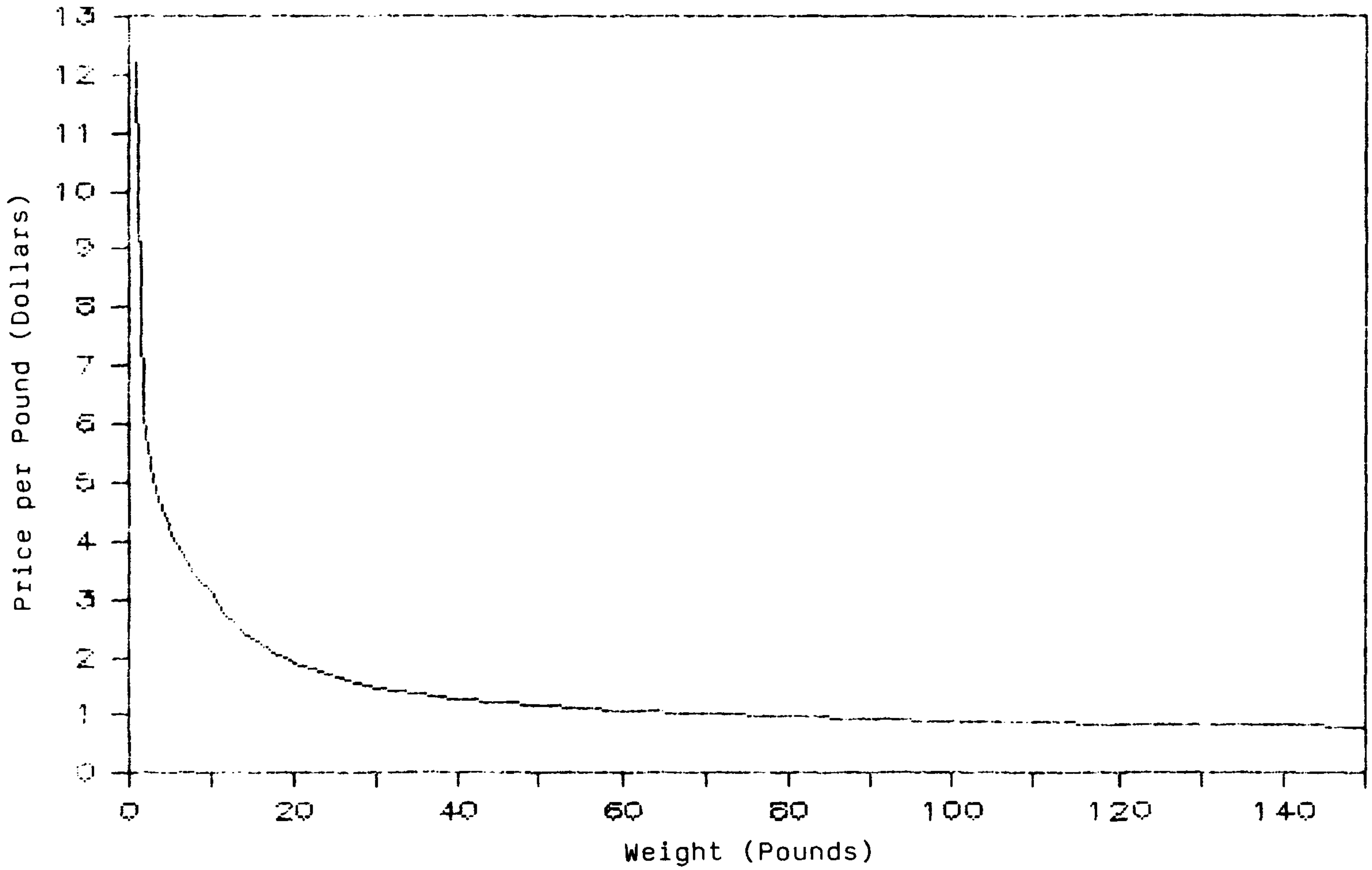


Fig 4.15 Price per Pound for Federal Express

to $1.80, and then remains fairly constant for the remaining 80 values, $1.80 to $1.00.

Conclusion. Federal Express should not be incorporated into a model as a constant figure in dollars per pound for all weights. Since 58% of all MICAP are 10 pounds or less, a significant error in estimating total cost would occur if the single figure were used. Using one cost for 1-10 pounds and a second for 11-150 improves overall accuracy.

United Parcel Service (UPS).

Weight vs Cost. As with previous modes, two distinct linear regions emerge. The difference with UPS is that the breakpoint occurs at a relatively large weight (50 pounds). The least squares line shows the deviation from a true linear relationship. Figure 4.16 shows how the two separate linear relationships relate, and how the superimposed least squares line accentuates the deviation from linearity. However, as Figures 4.17 and 4.18 show, plotting the two ranges separately (1-49 and 50-70) results in two linear plots develop.

Regression. A regression of weight vs cost confirms the initial analysis. The r squared for the entire range (1-70) is .973466 and the largest residual 123.2. Two separate regressions computed with weights less than 50 pounds and weights 50-70 pounds improves the r squared term and reduces the maximum residual in each of the ranges (Table 4.6).

Table 4.6

Improvement in Residuals for United Parcel Service

Range	r squared	Max Residual	Decrease in Residual
1-49	.99999	.41	99.5%
50-70	.99988	.55	99.6%

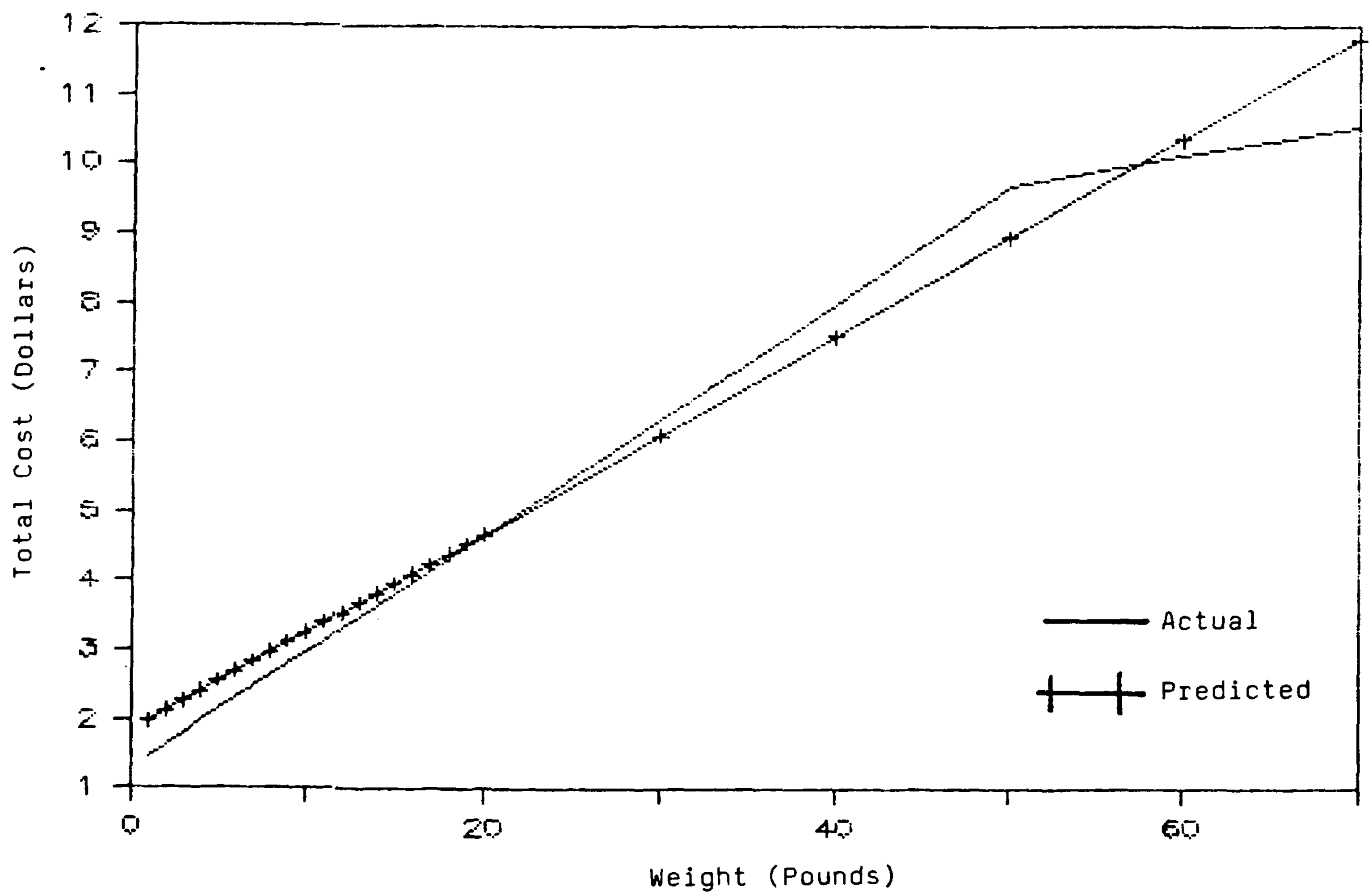


Fig 4.16 Comparison of Actual and Predicted Costs
United Parcel Service 1-70 Pounds

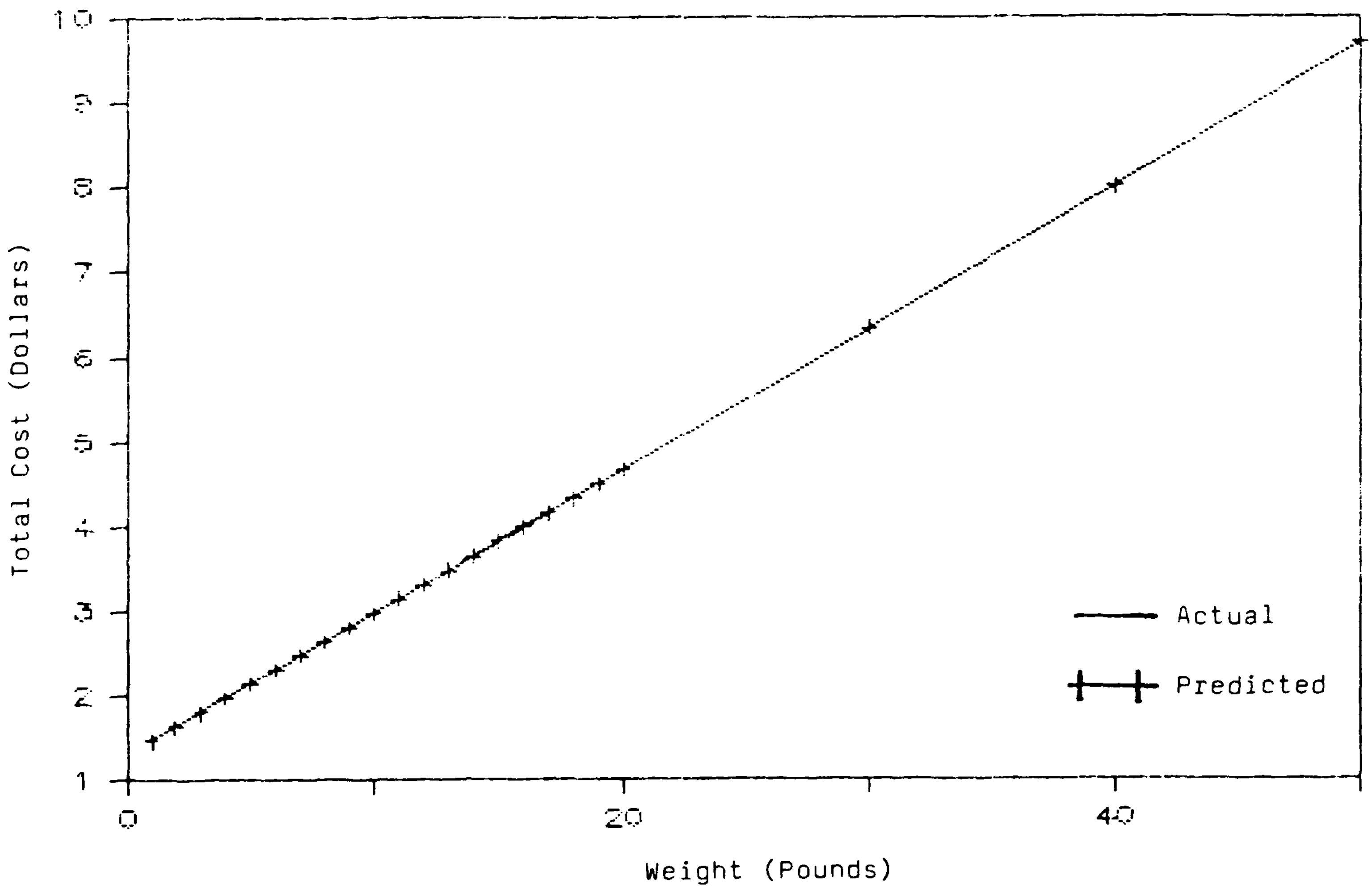


Fig 4.17 Comparison of Actual and Predicted Costs
United PARCEL Service 1-50 Pounds

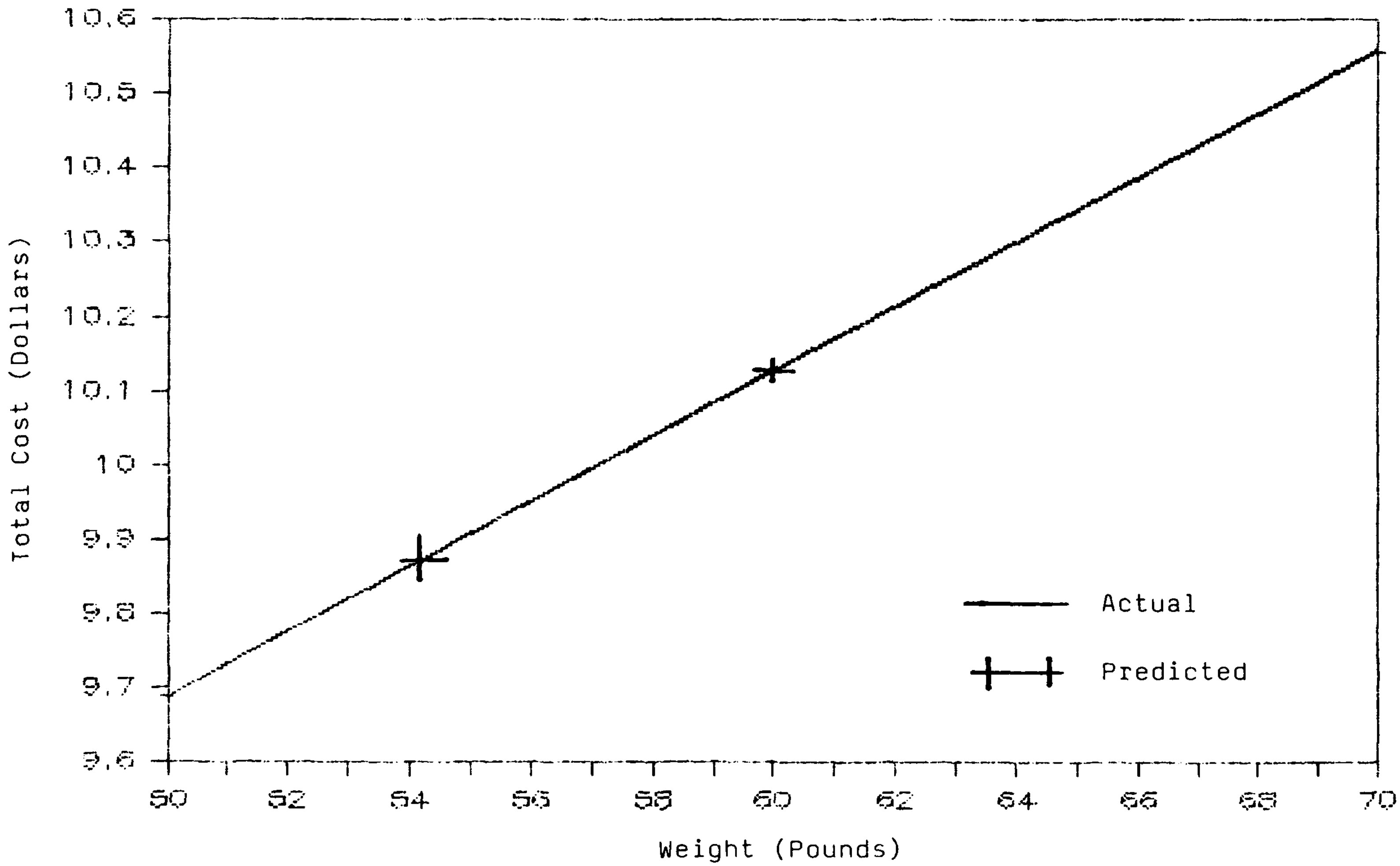


Fig 4.18 Comparison of Actual and Predicted Costs
United Parcel Service 50-70 Pounds

Weight vs Price per Pound. The cost of shipping expressed in dollars/pound decreases rapidly from 1-10 pounds (146 dollars/pound to 26 dollars/pound), but from 11-70 pounds the decrease is modest (26 cents/pound to 18 cents/pound). The behavior is similar to other modes, and confirms the assumption that in the weights above 10 pounds price/pound is fairly constant (Figure 4.19).

Conclusion. Accuracy would improve if two separate costs expressed in dollars/pound were used in a model. The first cost for weights from 1-50 pounds and the second from 50-70 pounds. However, since only 4% of all shipments fall between 50 and 70 pounds, a significant error would not be induced if a single value were assumed.

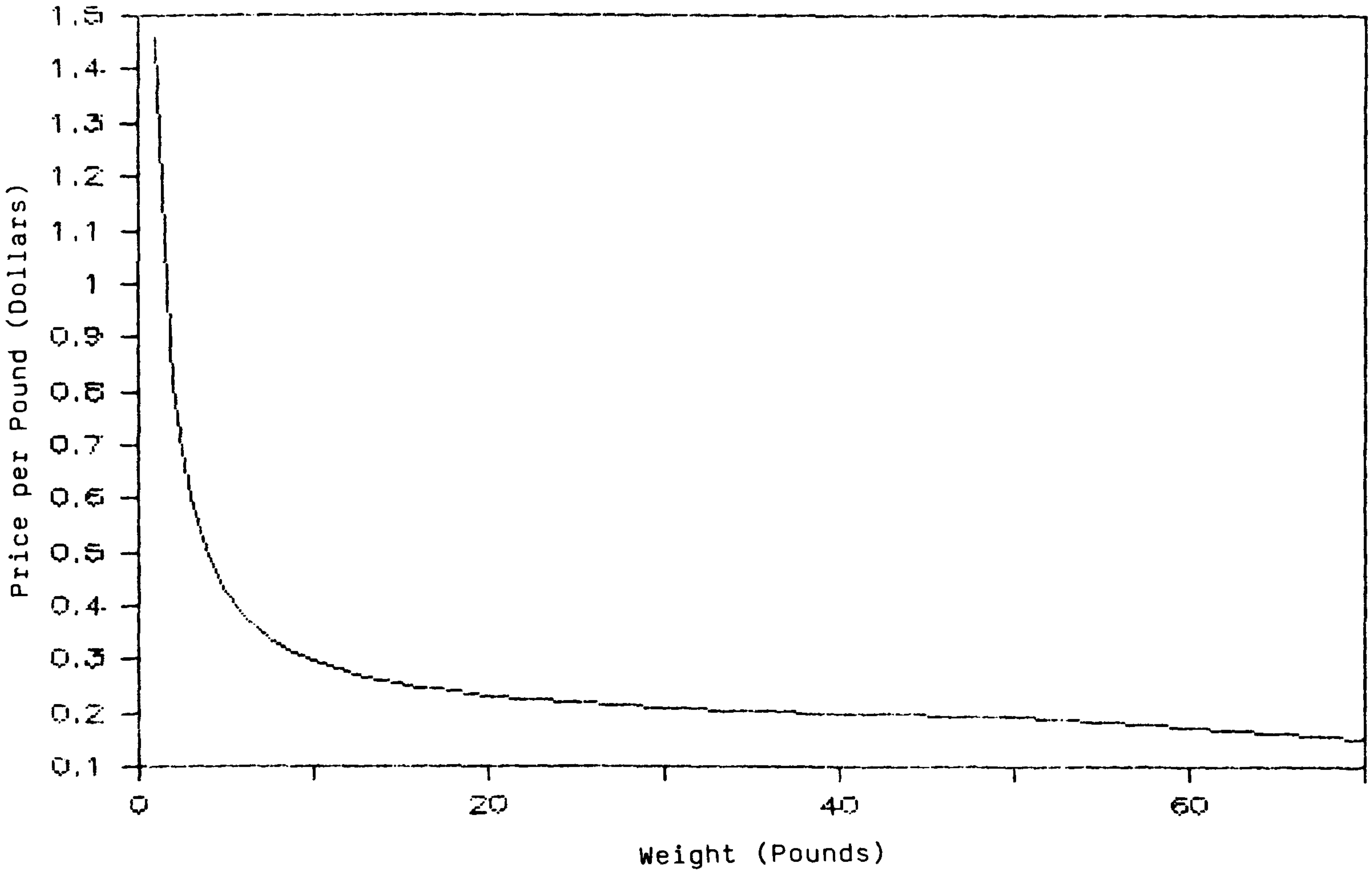


Fig 4.19 Price per Pound for United Parcel Service

Express Mail. Both next day express mail and two day delivery exhibit similar characteristics. Therefore, this analysis will consider them as one mode.

Weight vs Cost. The entire range is linear (Figure 4.20). Other commercial modes had two distinct linear ranges, but not express mail.

Regression. The r squared value for the entire range is .999981 and for weights greater than two pounds the largest residual is 2.614. Both values confirm that assuming a linear relationship over the entire range is a valid assumption.

Weight vs Price per Pound. Behavior is similar to other modes. The price/pound decreases rapidly for the first ten pounds and then remains fairly constant over the next 60 pounds (Figure 4.21).

Conclusion. The cost of Express Mail could be expressed as a single value since the relationship is basically linear.

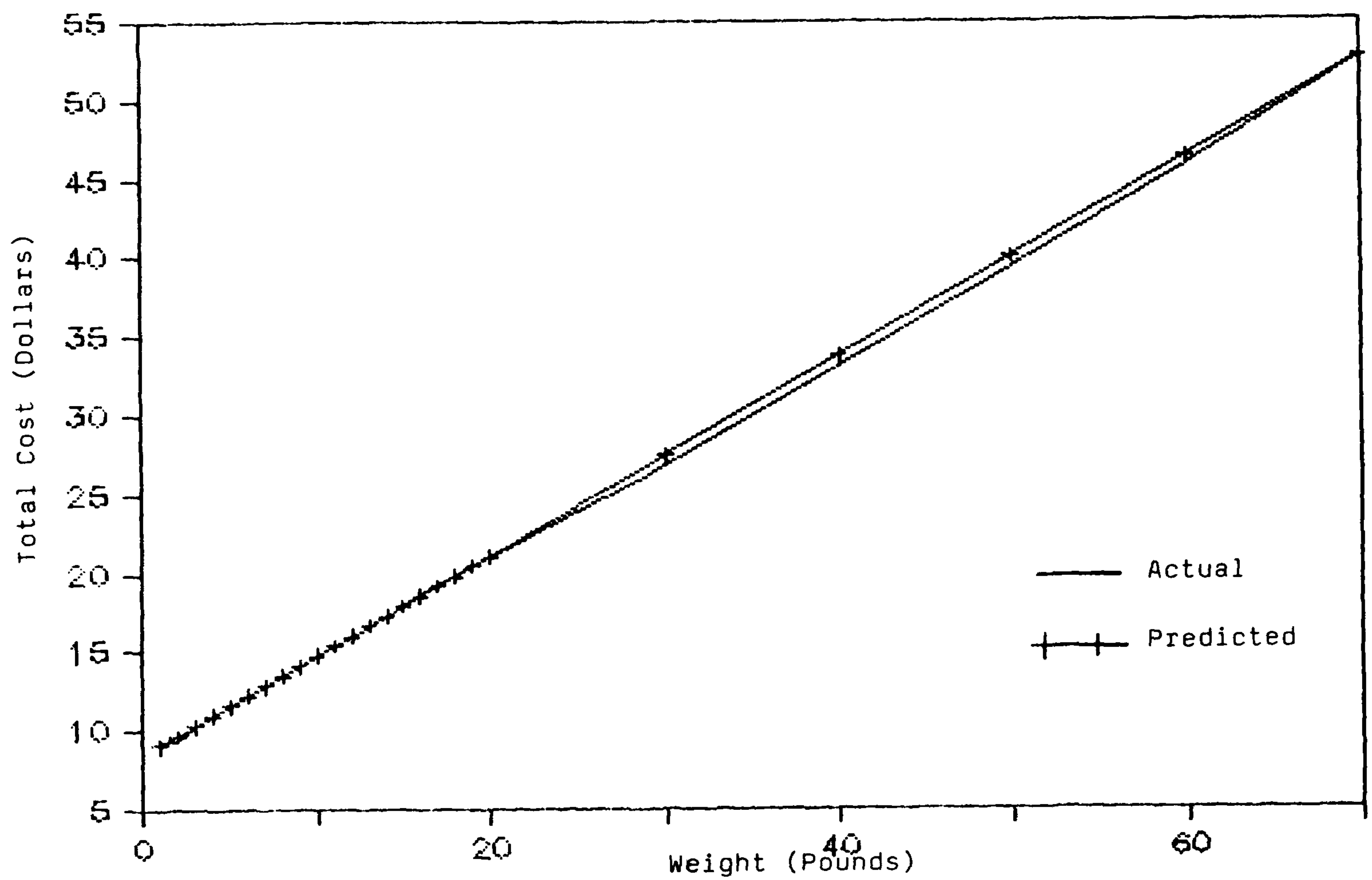


Fig 4.20 Comparison of Actual and Predicted Costs
Express Mail 1-70 Pounds

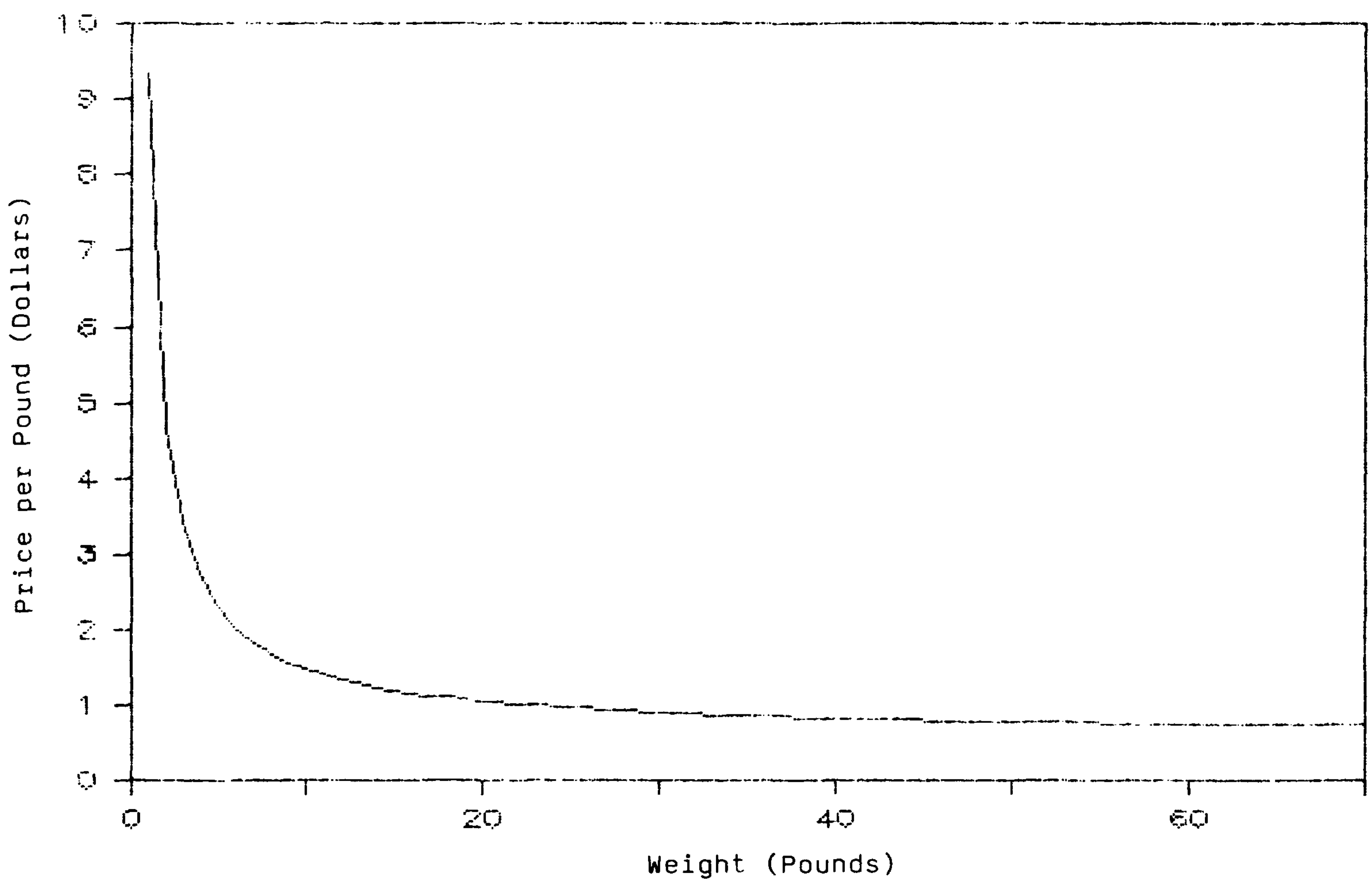


Fig 4.21 Price per Pound for Express Mail

Less-than-Truckload (LTL) Shipments. Since all LTL shipments exhibited the same basic characteristics, the cost of shipping from Sacramento to Boston was selected as typical, and will be the basis for this analysis.

Weight vs Cost. The function of price based upon weight approximates a linear relationship (Figure 4.22). The relationship is defined by a combination of linear functions because of the rate schedules, which set a price in cents/pound for various ranges: 0-500, 500-1000, 1000-2000, 2000-5000, and greater than 5,000. As weight increases, the cost in cents/pound decreases at the breakpoints, and that explains the plateaus that result. At certain weights the shipper pays more by declaring a heavier load than he/she actually is carrying, and therefore qualifies for the lower price/pound. In the trucking industry this legal practice is known as "shipping wind." The following example will illustrate this phenomenon:

Price per pound for 2000-5000 pounds=$.1095
Price per pound greater than 5000=$.0965 (42:447)
Weight of shipment=4750 pounds

4750 pounds X .1095=$520.13
5000 pounds X .0965=$482.50

Therefore, instead of declaring a shipment of 4750 pounds, the shipper declares 5000 pounds and saves $37.63. To compute the break even point in this example:

5000 pounds x $.0965/pound= BREAKEVEN WEIGHT x $.1095/pound
BREAKEVEN WEIGHT = (5000 x .0965)/.1095
BREAKEVEN WEIGHT = 4406.39 pounds

Therefore, any shipment between 4406.39 and 5000 pounds will be less expensive if declared as 5000 pounds and shipped at the 5000 pound rate.

Regression. Despite the plateaus and change in rates at several breakpoints, r squared is .99744. There is a strong linear relationship even when considering the entire range. Since the function is defined by constant linear relationships, and r squared=1 would be achieved by using the actually cost in cents/pound. The largest residual is 49.34 occurring at 4400 pounds. That is a logical point to have a large residual, since that is the start of the largest plateau in the original graph (Figure 4.22).

Weight vs Price per Pound Figure 4.23 displays the strong linear relationship. The price break points can also be seen. The conclusion is that the price/pound is not constant over the entire function, but can be assumed to be approximately linear for weights over 2000 pounds.

Conclusion. Two values, expressed in cents/pound, should be used in a final model. The first value would be for shipments 2000 pounds or less, and the second for shipments greater than 2000 pounds.

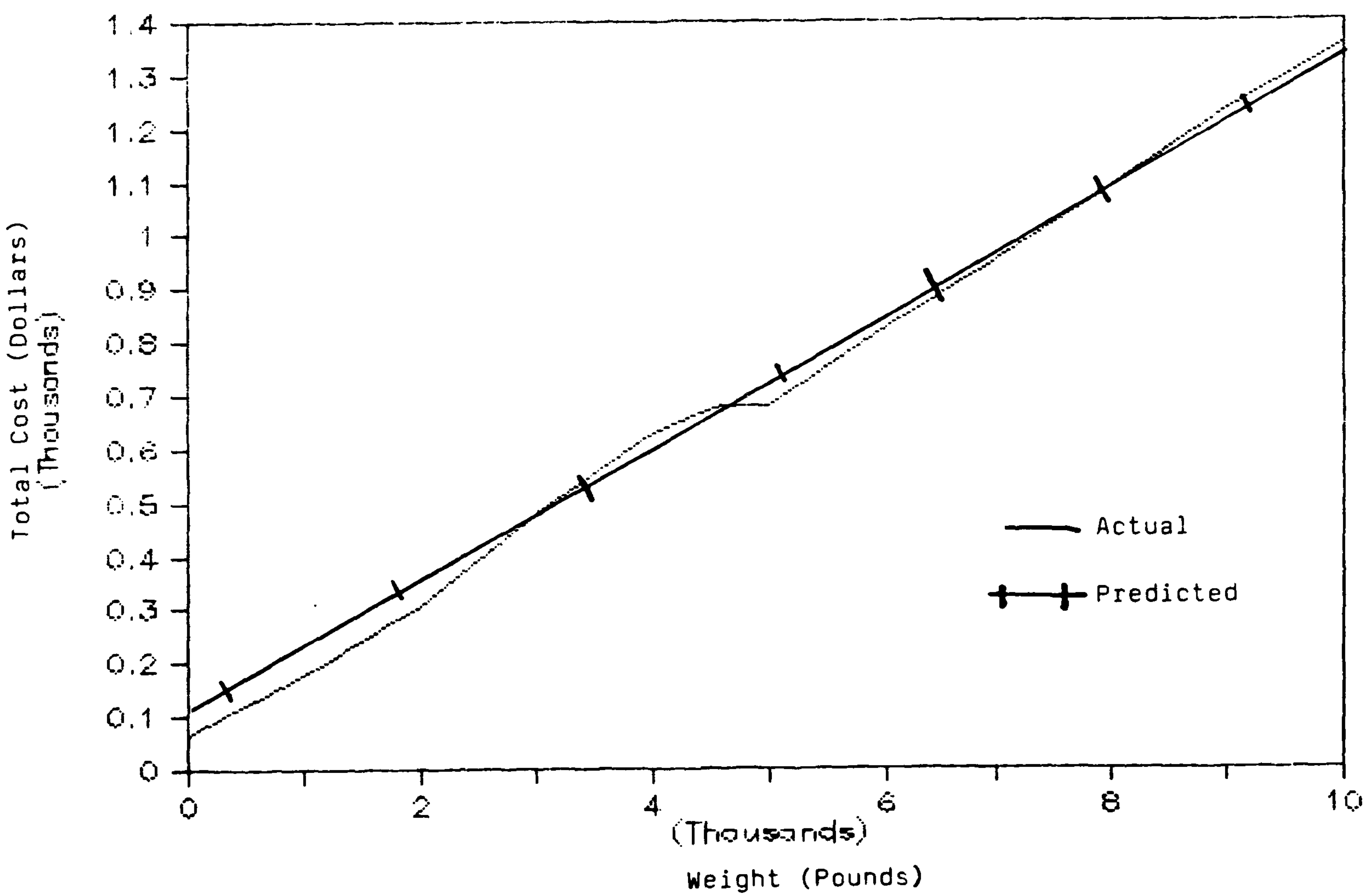


Fig 4.22 Comparison of Actual and Predicted Costs
Less-than-Truckload 1-10,000 Pounds

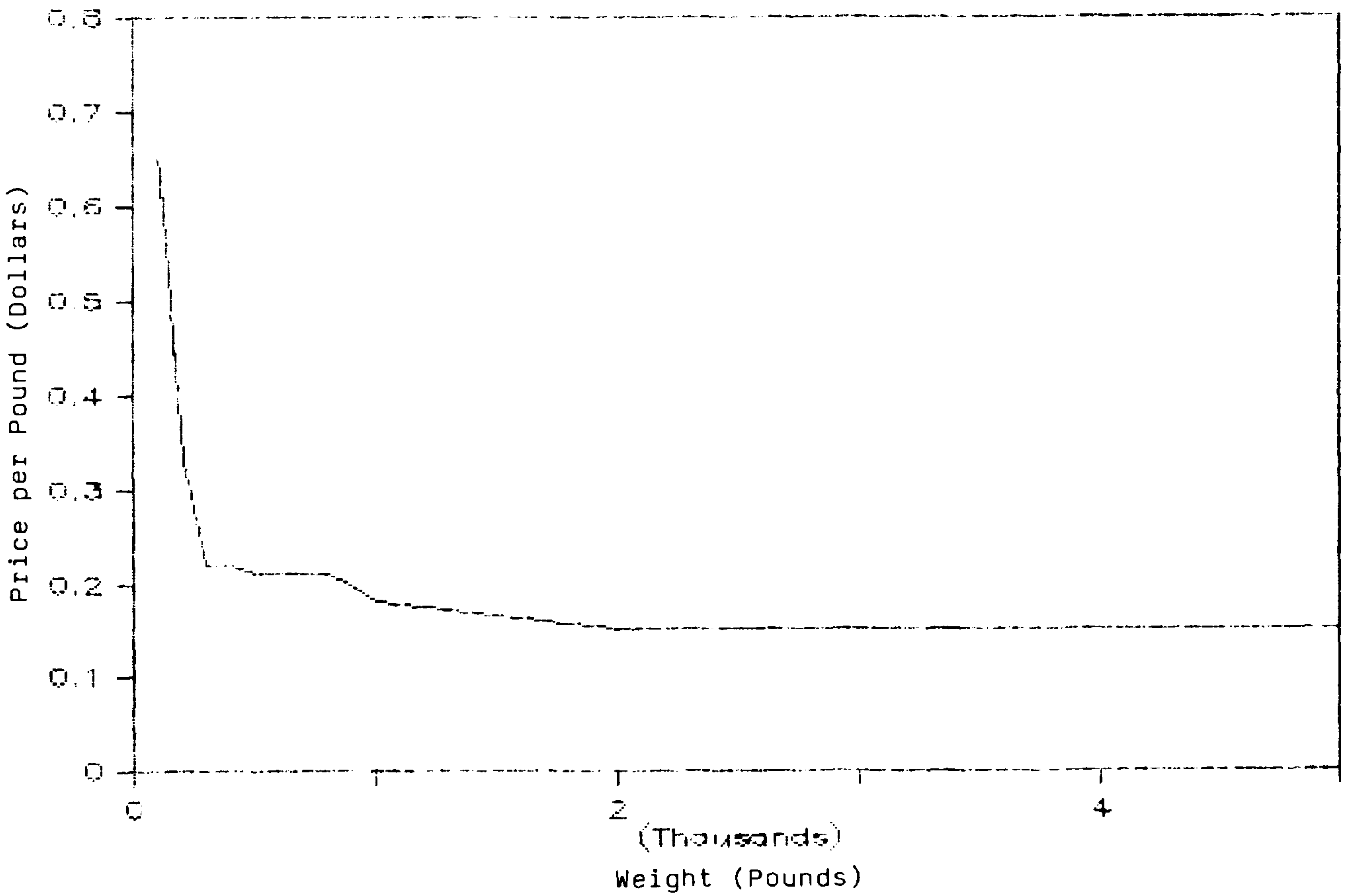


Fig 4.23 Price per Pound for Less-than-Truckload

Impact of Assuming Linearity in a Final Model.

First Class Mail. Assuming linearity for first class mail pricing affects the 80% of the TP 1 shipments that are less than 70 pounds. That equates to 462,000 shipments in the 6-month study, therefore an accurate fiqure expressed in cents/pound is required in the final model.

As noted in the previous section, two ranges of linearity are present in first class mail pricing (1-10 and 11-70). Since 58.75% of all TP 1 shipments are less than 11 pounds and 28.75% are two pounds or less, any assumption about a constant price/pound must be accurate at the lower weights. If a single range of 1-70 pounds was used to compute a least squares line, a 10% error at one pound and 13% at two pounds would result.

However, by lumping one and two pound shipments together (they are the same price) and using two ranges, the error at the one and two pound combination is only 4.5%, a 55% and 65% improvement over the errors using the entire range. Considering the 41.25% of the shipments that are greater than 10 pounds, using two ranges of linearity results in virtually no error terms. The largest is .06%.

Based upon these findings, any model must insure that the pricing at the lower weights is accurate for first class mail. A price based upon the least squares line for 1-70 pounds is not accurate.

Federal Express. Since Federal Express provides next day priority service, virtually the only products that would want to vie for the premium transportation are MICAP shipments. Therefore, for the purpose of this analysis only MICAP will be considered. In the population collected for this analysis, 91% of all MICAP shipments are 150 pounds or less and therefore, eligible for Federal Express service. However, assuming a constant price/pound over the entire range induces a large error at the smaller weights. If a constant price/pound is assigned based upon the least squares line, a 94% error ($11.49/$12.20) in predicting the price for two pounds and 88.6% ($10.81/$12.20) error for one pound will be induced. Since 60% of all MICAP shipments are two pounds or less, the impact on the final result would be significant. For the weights above 10 pounds, the largest error, 6%, occurs at 12 pounds, which is 4% of all MICAP shipments.

By separating the Federal Express graph into two separate linear regions (1-10 and 11-150) the error predictions in both regions are reduced. The largest error for less than 10 pounds is 8%, down from 94%, and every weight above 10 pounds has an error term of zero. Based upon these findings, any model that incorporates Federal Express pricing in dollars/pound should have at least two separate prices expressed in dollars/pound.

Express Mail. Express Mail is a mode that would be used for MICAP and TP 1 shipments only, since the mode is designed for fast overnight or two day service. Because of the fast response, the price is comparable to Federal Express. Since the findings for overnight and two day service were basically the same, the figures used in this section are for overnight service. The largest error prediction for Express Mail using the least squares line was 4.5% at two pounds, more accurate than even the Federal Express price after being separated into two zones. All weights greater than two pounds produce a error term of approximately zero. Therefore, in a strategic planning model, the Express Mail node could be assigned a single price/pound and produce accurate results.

<u>Relationship of Weight and Cost with Distance Not Fixed.</u> As with the previous analysis, the modes displayed different characteristics, and therefore, must be analyzed separately. Table 4.6 contains a summary of the findings for this section. The following sections explain the findings.

<u>First Class Mail.</u> For weights greater than 10 pounds a significant error would be induced if the weight were assumed constant regardless of the distance shipped. Figure 4.24 shows two separate ratios: cost of shipping to zone 4/cost of shipping to zone 8 and cost of shipping to zone 7/cost of shipping to zone 8. The price to ship more than 10 pounds to Zone 4 is an almost constant 60% of the price to ship to Zone 8. For weights greater than 10 pounds, the price to Zone 7 is approximately 89% of the price to Zone 8.

Table 4.7

Cost Ratio for Shipments to Different Zones

MODE	ZONE A	ZONE B	COST RATIO(ZONE A/ZONE B) LARGEST	SMALLEST
FIRST CLASS MAIL	4	8	1.0	.58
FIRST CLASS MAIL	7	8	1.0	.88
SURFACE PARCEL	4	8	.72	.31
SURFACE PARCEL	7	8	1.0	.70
UNITED PARCEL	4	8	.84	.44
UNITED PARCEL	7	8	.96	.84
EXPRESS MAIL	4	8	1.0	.62
EXPRESS MAIL	7	8	1.0	.87
LTL	4	8	.64	.57
LTL	7	8	.88	.77

Surface Parcel Post. Of all the modes examined, surface parcel post displayed the most dramatic differences. When comparing Zone 4 to Zone 8, Zone 4 is 30% of the cost of Zone 8 for shipments over 30 pounds, while for shipments under 30 pounds the range is from 42-72%, with most being under 50% (Figure 4.25). When comparing shipments to Zone 7 with shipments to Zone 8, the cost can be assumed constant until 30 pounds at which point the rate drops to 70%.

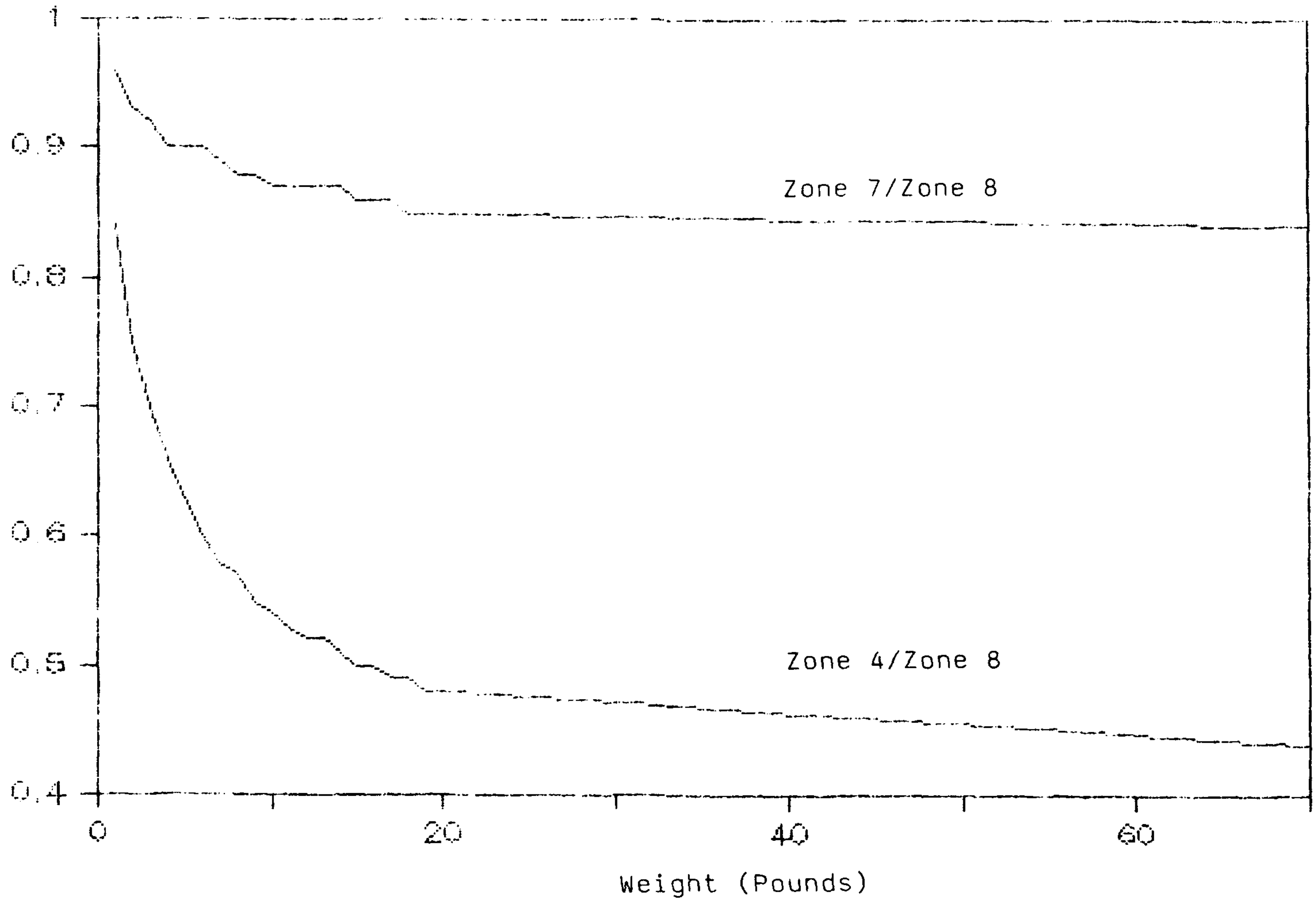


Fig 4.24 Ratio of Zone Costs: First Class Mail

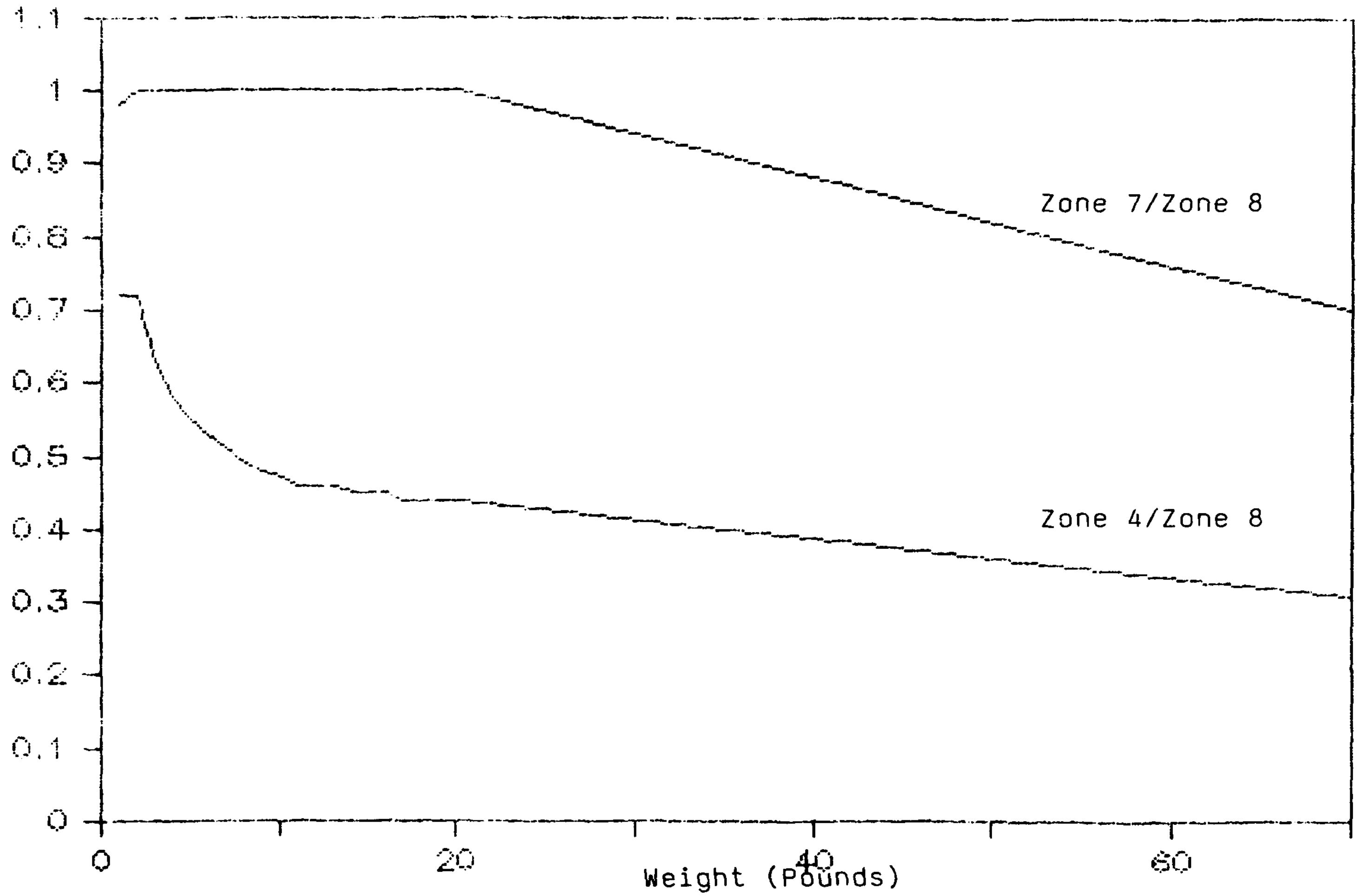


Fig 4.25 Ratio of Zone Costs: Surface Parcel Post

United Parcel Service. The same general principle applies to UPS as to first class mail, although for different percentages and weights. The price of shipping to Zone 4 is 48% of the price to ship to Zone 8 for weights greater than 20 pounds (Figure 4.26). Even if a middle figure were used, a 26% error would be induced in any model. Comparing Zone 7 to Zone 8, the rate is 84-86% less for shipments above 18 pounds. Although not as great as the zone 4 to zone 8 ratio, a 7% error would be induced if costs were considered independent of distance traveled.

Express Mail. Express mail was unique in the behavior exhibited when plotting the ratio of the cost of shipping to Zone 4 and to Zone 8 as a function of weight. The function had an exponential distribution quality, which approached a linear relationship around 30 pounds (Figure 4.27). At 30 pounds, Zone 4 is 65-66% the rate for Zone 8. The ratio of cost to Zone 7 divided by cost to Zone 8 as a function of weight is also exponential, with a fairly linear relationship greater than 25 pounds. At that point Zone 7 is 88-89% of the cost of Zone 8.

Less-than-Truckload. For this comparison, the rates for shipments from Sacramento ALC to a base in zones 4 and 7 were divided by the rates to a base in zone 8 (Figure 4.28). Up until approximately 4000 pounds the ratio is from 64-69%, at 4000 pounds the ratio drops to a constant 57%. Since the rate in dollars/pound does not change, the 57% ratio remains constant for the remainder of the function.

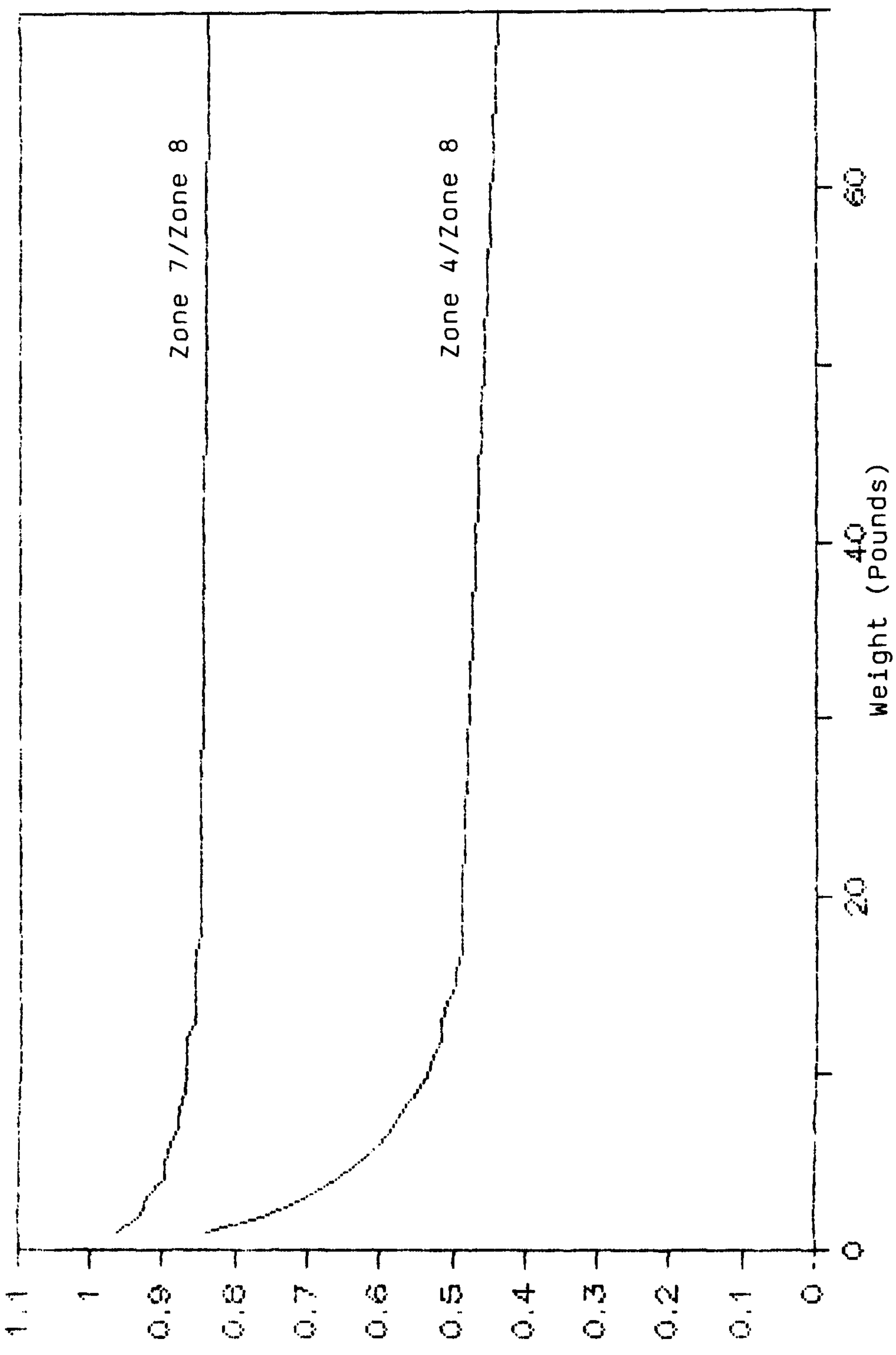


Fig 4.26 Ratio of Zone Costs: United Parcel Post

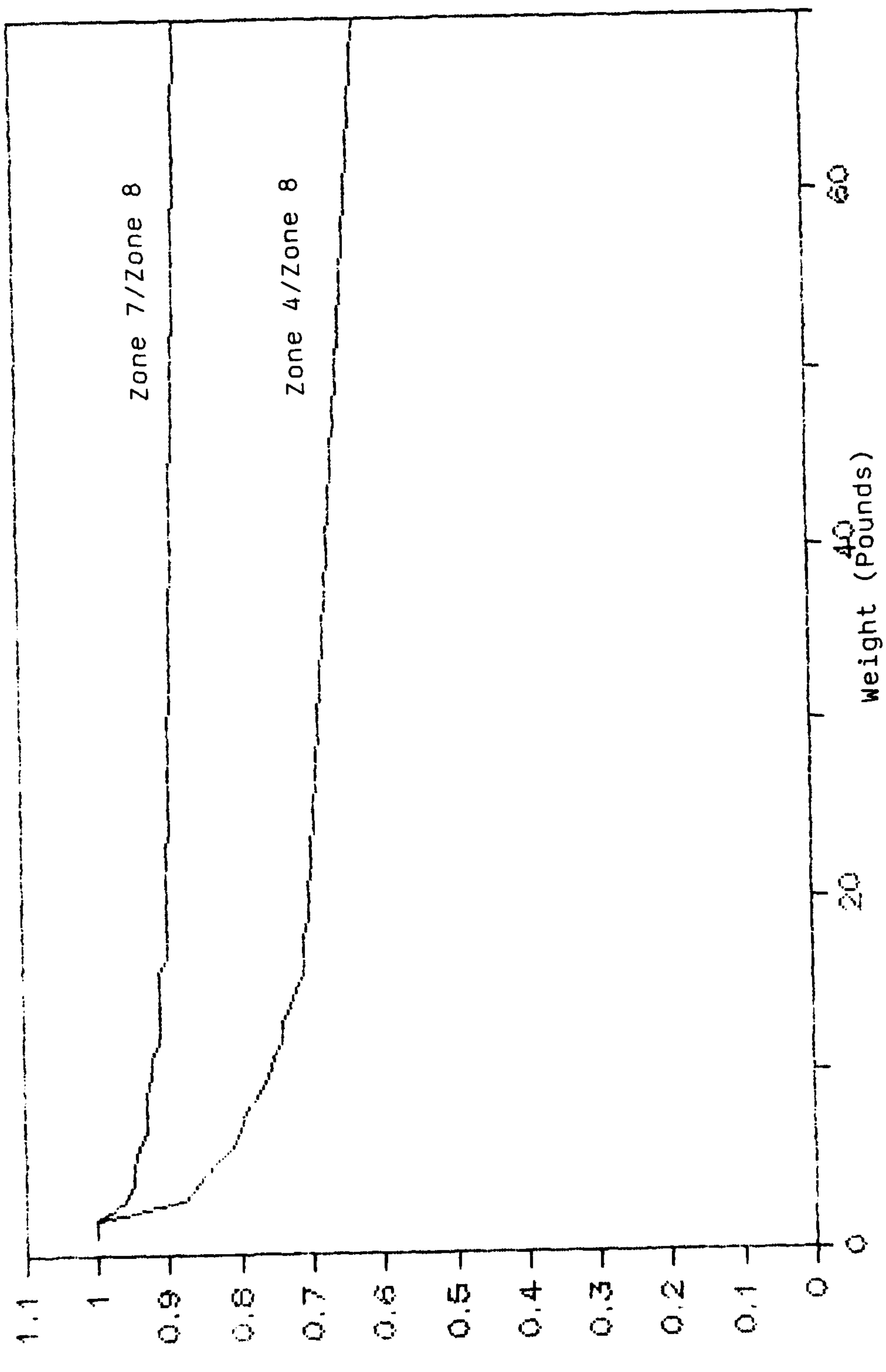


Fig 4.27 Ratio of Zone Costs: Express Mail

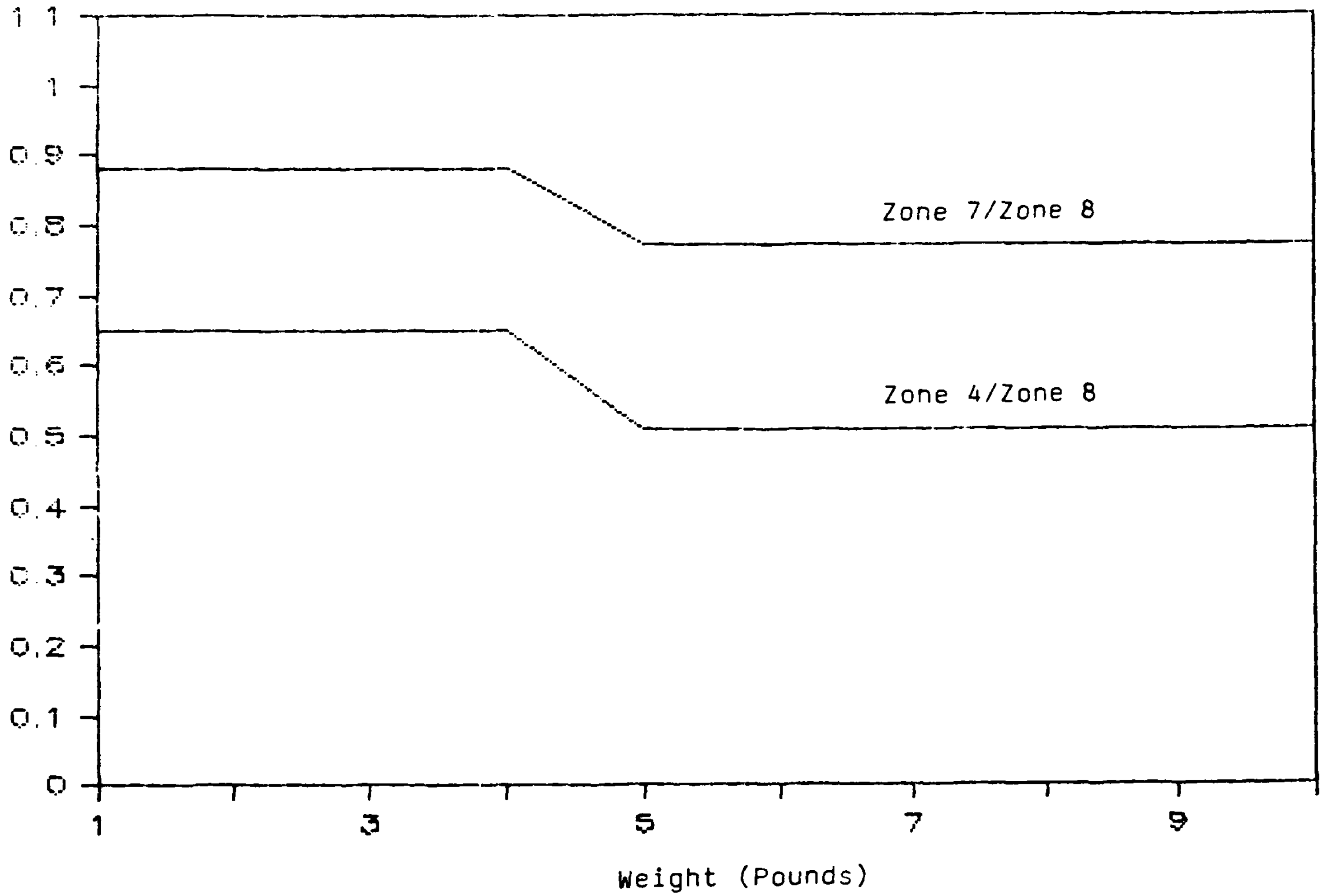


Fig 4.28 Ratio of Zone Costs: Less-than-Truckload

V. Cost Comparisons

This chapter presents the background, methodology and findings for research objective #4:

> Compute the actual LOGAIR costs for specific traffic channels and compare those costs to the LOGAIR Tariffs charged DOD and to the costs for similar service on common carrier transportation companies.

The Air Force transportation manager needs to understand the true cost of dedicated contract service to fully appreciate the value of the service.

Background for LOGAIR Cost Comparisons

Transportation modes that provide similar levels of service offer the opportunity for direct cost comparisons. Of particular interest are the costs for dedicated contract service versus nondedicated common service. The costs of dedicated contract service provided by LOGAIR has been under Congressional scrutiny principally due to the tremendous growth of competitive common service in the last decade.

Although the tariff rates for common carriers are readily available, comparison of these tariff rates to actual shipment costs on LOGAIR is difficult due to the contracting procedure used for the service. As previously stated, LOGAIR is an "air transportation system," and HQ AFLC submits an annual request for the complete air transportation service, with the Military Airlift Command actually contracting for the service (35). Consequently, determining the costs for individual shipments requires consideration of the total payments made to LOGAIR carriers and estimation of the actual service provided by the carriers. HQ AFLC/DSTMA computes the charges for reimbursable traffic entering the LOGAIR System, and publishes these LOGAIR Tariffs annually. This thesis offers an alternative method for computing the actual costs of LOGAIR shipments, realizing these computations only consider the variable costs directly associated with contracting the carriers' services, and not the fixed costs associated with administration, air terminal facilities, and manning of facilities.

Comparison of LOGAIR to alternative modes allows the transportation manager to judge if cargo shipments are worth the true costs of LOGAIR. As established earlier, for shipments with certain size, weight, and special handling characteristics, or on certain traffic channels, there is no alternative to LOGAIR. In those cases, the service is undeniably worth the cost.

The first objective was to determine the costs of LOGAIR in cents per pound for various distances, based on all shipments moved by LOGAIR. The research questions for this objective were as follows:

1. On what basis are LOGAIR carriers paid?

2. What are the fuel costs for LOGAIR?

3. What percentage of LOGAIR capability is actually utilized?

4. Based on the answers to questions 1-3, what are the actual costs for LOGAIR service in cents per pound for different distances, and how do these costs compare to the LOGAIR Tariffs charged DOD shippers?

5. How do actual LOGAIR costs compare to the tariff rates of common carriers offering similar service?

A second consideration in analyzing the true costs of LOGAIR is that not all LOGAIR shipments need this high priority service. Those shipments are carried due to excess capacity in the system. That is, the high priority shipments do not fill the entire aircraft, and therefore, additional lower priority cargo or shipments capable of being transported by common carrier are flown on contract air. This additional cargo may hide the true cost of LOGAIR service or may be responsible for excessive LOGAIR service.

The second objective was to determine the costs of LOGAIR in cents per pound for various distances based on the shipments that require LOGAIR service. The research questions for this objective were as follows:

1. What percentage of actual LOGAIR shipments are considered eligible for air transportation?

2. What percentage of actual LOGAIR shipments are considered as requiring air transportation?

3. Using the answers to questions 1 and 2, and calculations from the first objective, what are the costs for LOGAIR service in cents per pound based on the shipments that need LOGAIR service?

Methodology for LOGAIR Cost Comparisons

The methodology for determining actual LOGAIR costs is the key to comparing the costs of the dedicated contract service provided by LOGAIR to the costs of available nondedicated common service. Determining LOGAIR costs required information on route structure, type aircraft and aircraft cargo-carrying capability, actual utilization of capability, government fuel costs, contract payment schedules, and priority requirements of the cargo that moved on LOGAIR. Analysis of this information provided the method for determining LOGAIR costs. The common carrier rates were provided by traffic managers (18) and United States Postal Service employees at Wright-Patterson AFB (WPAFB).

During the research period LOGAIR's route structure consisted of nine trunk routes and seven feeder routes, providing service to 56 LOGAIR stations. The LOGAIR stations transhipped cargo destined for other locations by various modes of surface transportation. AFLC contracted with six air carriers to serve the 16 routes, with the goal for utilization of aircraft cargo-carrying capability set at 82% for the trunk routes and 70% for the feeder routes(47). The air carriers were paid a contracted plane mile rate (dollars per mile by aircraft type) for the standard routes, and were paid the same rate regardless of actual utilization of aircraft cargo-carrying capability. The air carriers were also paid $250 per landing. Another expense was a 4.5% transportation tax based on payments to the air carriers.

Fuel costs were paid by the government up to a maximum based on authorized fuel burn rates (gallons per mile). The authorized fuel burn rates were based on direct air miles, adjusted for expected indirect routing and landing delays.

As a result, the fuel burn rates varied between the different routes. Fuel consumption beyond the authorized amount required adjustment in payments to the air carrier. Computation of fuel costs was based on 93 cents per gallon.

The LOGAIR route stucture diagram (Figure 5.1) and Table 5.1 describe LOGAIR for the six month period of study. Route structure and schedules, aircraft type and cargo-carrying capability, and average route utilization rates were provided by HQ AFLC/DSTMA (47). Plane mile rate and landing costs, transportation tax rates, fuel burn rates and cost, and flight planned route distances were provided by HQ AFLC LOC/XOLG (37). This information allowed computation of actual costs for contracted service between any origin-destination (O-D) pair of LOGAIR stations. Dividing that cost by the average total cargo weight, based on aircraft cargo capacity and the route utilization rate for the traffic channel, provided actual shipment costs in cents per pound. Determining the actual costs in cents per pound based on air eligible cargo (TP 1 and TP 2), or based on air priority cargo (TP 1 only) required further calculations.

According to the data collected by HQ AFLC/DST, 95.42% of all LOGAIR cargo weight was TP 1 or TP 2; and 58.76% was TP 1. Taking these percentages of average total cargo weight as the basis for determining actual costs in cents per pound provided insight into the costs of LOGAIR for air eligible cargo and for air priority cargo. Air Force shippers typically consider low priority cargo moved on the

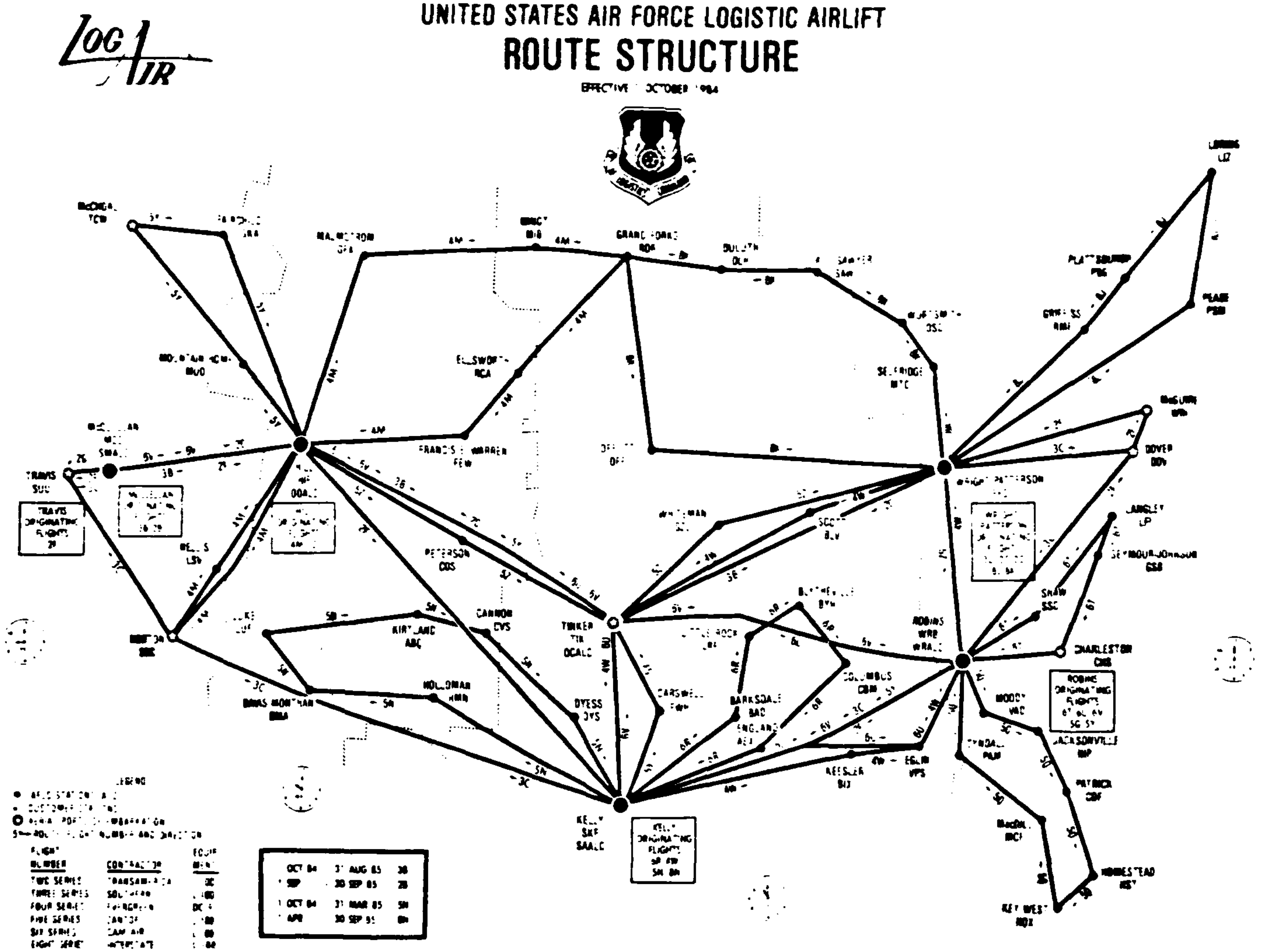


Fig 5.1 LOGAIR Route Structure

TABLE 5.1

Inputs for LOGAIR Cost Computations

Air Carrier	Route	Type Aircraft	Cargo Capacity (Pounds)	Route Utilization (Percent)	Plane Mile Rate (Dollars/Mile)	Fuel Burn Rate (Gallons/Mile)
Transamerica	2F	L-100	40981	65.2%	4.9279	2.600
Transamerica	2G	L-100	40981	70.7%	4.9279	2.600
Southern	3B	L-100	40981	80.1%	4.9279	2.600
Southern	3C	L-100	40981	70.1%	4.9279	2.600
Evergreen	4M	DC-9	28541	71.8%	3.4228*	2.314
Evergreen	4W	DC-9	28541	89.4%	3.4228*	2.525
Zantop	5N	L-188(2dr)	28640	81.2%	3.7680	2.610
Zantop	5Q	L-188(2dr)	28640	62.2%	3.7680	3.210
Zantop	5Y	L-188(2dr)	28640	83.2%	3.7680	2.443
Zantop	5Z	L-188(2dr)	28640	89.8%	3.7680	2.188
Cam Air	6R	L-188(1dr)	27502	71.8%	3.7680	2.739
Cam Air	6T	L-188(1dr)	27502	76.0%	3.7680	3.154
Cam Air	6U	L-188(1dr)	27502	91.4%	3.7680	2.421
Cam Air	6V	L-188(1dr)	27502	93.0%	3.7680	2.405
Interstate	8J	L-188(2dr)	28640	73.2%	3.7680	2.401
Interstate	8K	L-188(2dr)	28640	62.8%	3.7680	2.422

* Adjusted for excess fuel consumption. Contracted plane mile rate of $3.7680 minus $.3452 per mile fuel penalty equals $3.4228 equivalent plane mile rate.

excess capacity of LOGAIR flights as "free" transportation. Therefore, determining LOGAIR costs as above was a legitimate method of accounting for the costs of LOGAIR service.

This thesis investigated these actual LOGAIR costs for five O-D pairs of LOGAIR stations. Using Wright-Patterson AFB as the origin, one destination was randomly selected based on direct distances that approximated 500, 1000, 1500, 2000, and 2500 miles. Traffic channels with these distances provided useful information about common carriers with zone-determined rates. Table 5.2 presents the five traffic channels, the LOGAIR routes that connect those (O-D) pairs, and the corresponding zones used by the United States Postal Service and United Parcel Service.

Table 5.2

Traffic Channels for Cost Comparisons

Traffic Channels	Route(s)	Zone
Wright-Patterson AFB - Langley AFB	5Z/6T	4
Wright-Patterson AFB - Loring AFB	8J	5
Wright-Patterson AFB - Kirtland AFB	3C/5N	6
Wright-Patterson AFB - Nellis AFB	2G/4M	7
Wright-Patterson AFB - McChord AFB	2G/5Y	8

The routing for the traffic channels used in the research was based on the _United States Air Force Logistics Airlift FY85 Flight Schedules and Routing Guide_ (42). In cases where alternate routes were available, the shortest route with seven-day service was selected. The costs for LOGAIR in cents per pound was computed for each traffic channel, developing these costs based on total cargo weight, air eligible cargo weight, and air priority cargo weight. Routing for traffic channels with transhipment of cargo on more than one LOGAIR standard route required costs computations for each route segment and then addition of these route segment costs. The Wright-Patterson AFB - Langley AFB traffic channel is presented as an example of these computations.

Wright-Patterson AFB - Langley AFB

1. Cargo for this traffic channel moved via Route 5Z to Warner-Robins AFB, then was transhipped on Route 6T to Langley AFB with one intermediate stop at Shaw AFB.

2. Route 5Z was served by Zantop's L-188(2dr), which has a cargo capacity of 28640 pounds. The route utilization was 89.8%, the plane mile rate was $3.7680, the fuel burn rate was 2.188, and the route segment distance was 496 miles.

Route 6T was served by Cam Air's L-188(1dr), which has a cargo capacity of 27502 pounds. The route utilization was 76.0%, the plane mile rate was $3.7680, the fuel burn rate was 3.154, and the route segment distance was 518 miles.

3. Payments to carriers were determined as follows:

[(Distance x Plane Mile Rate) + Landing Costs] + 4.5% Tax

[(496 x $3.7680) + $250] + 4.5% Tax
$2118.93 + (.045 x $2118.93)
$2214.28 (Carrier Payment for 5Z route segment)

[(518 x $3.7680) + $500] + 4.5% Tax
$2451.82 + (.045 x $2451.82)
$2562.16 (Carrier Payment for 6T route segment)

4. Route segment fuel costs were determined as follows:

(Distance x Burn Rate) x $.93 = Fuel Cost

(496 x 2.188) x $.93 = $1009.28 (Route Segment 5Z)
(518 x 3.154) x $.93 = $1519.41 (Route Segment 6T)

5. Route segment total costs were determined as follows:

Carrier Payments + Fuel Costs = Total Costs

$2214.28 + $1009.28 = $3223.56 (Route Segment 5Z)
$2562.16 + $1519.41 = $4081.56 (Route Segment 6T)

6. Route segment cargo weight was determined as follows:

Cargo Capacity x Utilization Rate = Total Cargo Weight
Total Cargo Weight x 95.42% = Air Eligible Cargo Weight
Total Cargo Weight x 58.76% = Air Priority Cargo Weight

28640 lb x 89.80% = 25719 lb (Total Cargo Weight) (5Z)
25719 lb x 95.42% = 24541 lb (Air Eligible Cargo Weight)
25719 lb x 58.76% = 15112 lb (Air Priority Cargo Weight)

27502 lb x 76.00% = 20902 lb (Total Cargo Weight) (6T)
20902 lb x 95.42% = 19945 lb (Air Eligible Cargo Weight)
20902 lb x 58.76% = 12282 lb (Air Eligible Cargo Weight)

7. Route segment costs per pound based on Total Cargo Weight, Air Eligible Cargo Weight, and Air Priority Cargo Weight were determined as follows:

Total Costs/Cargo Weight = Costs Per Pound

$3223.56/25719 lb = $.1253/lb (Total Cargo 5Z)
$3223.56/24541 lb = $.1314/lb (Air Eligible Cargo 5Z)
$3223.56/15112 lb = $.2133/lb (Air Priority Cargo 5Z)

$4081.57/20902 lb = $.1953/lb (Total Cargo 6T)
$4081.57/19945 lb = $.2046/lb (Air Eligible Cargo 6T)
$4081.57/12282 lb = $.3323/lb (Air Priority Cargo 6T)

8. Traffic channel costs per pound based on Total Cargo Weight, Air Eligible Cargo Weight, and Air Priority Cargo Weight were determined as follows:

5Z Costs/lb + 6T Costs/lb = Traffic Channel Costs/lb

$.1253/lb + $.1953/lb = $.3206/lb (Total Cargo)
$.1314/lb + $.2046/lb = $.3360/lb (Air Eligible Cargo)
$.2133/lb + $.3323/lb = $.5456/lb (Air Priority Cargo)

The LOGAIR cents per pound shipment costs for the five traffic channels were computed using total cargo weight, air eligible cargo weight, and air priority cargo weight as the costs bases. Then, typical LOGAIR shipment weights based on the 25th percentile, the 50th percentile (median), and the 75th percentile of all LOGAIR shipments were determined, and the costs of these typical LOGAIR shipments were calculated using the cents per pound rates. The LOGAIR costs of these typical shipment weights were then compared with the Logair Tariffs (26) and the tariff rates for alternative common carrier modes.

Cost Comparison Findings

Table 5.3 presents the shipment costs in cents per pound for the five traffic channels. LOGAIR shipment costs based on total cargo weight, air eligible cargo weight, and air priority cargo weight are designated LOGAIR Rate 1, LOGAIR Rate 2, and LOGAIR Rate 3, respectively. For the two

Table 5.3

Shipment Costs in Cents Per Pound

	LOGAIR Rate 1	LOGAIR Rate 2	LOGAIR Rate 3	LOGAIR Tariff
WPAFB to Langley AFB	.32	.34	.55	.16
WPAFB to Loring AFB	.33	.34	.56	.34
WPAFB to Kirtland AFB	.95	.99	1.61	.46
WPAFB to Nellis AFB	.69	.73	1.18	.61
WPAFB to McChord AFB	.65	.69	1.12	.70

destinations with nearly direct routing, Loring AFB and McChord AFB, the LOGAIR Rate 1 closely approximates the LOGAIR Tariff. Conversely, for the two destinations with very indirect routing, Langley AFB and Kirtland AFB, the LOGAIR Rate 1 is twice the LOGAIR Tariff. Since LOGAIR Tariffs are based on direct distances, this indicates that the LOGAIR Tariff and the LOGAIR Rate 1 cost computation methods are similar, other than the distance factor applied. Therefore, LOGAIR Tariffs do not recoup the actual shipment costs for total cargo moving via indirect routing.

The LOGAIR Rate 3, based on air priority cargo only, far exceeds the LOGAIR Tariff for all traffic channels. Two viewpoints are possible. If all cargo shipped is charged the LOGAIR Tariff, or similarly the LOGAIR Rate 1, then the movement of air eligible and lower priority cargo subsidizes the movement of air priority cargo. In contrast, if the movement of the air eligible and lower cargo is viewed as opportune or free due to the excess capacity on LOGAIR, then the charges for air priority cargo should approximate the LOGAIR Rate 3.

The common carrier modes selected for comparison with LOGAIR were as follows:

1. United Parcel Service (UPS)
2. First Class Mail (USPS)
3. Express Mail (USPS) next day delivery
4. Federal Express next morning delivery
5. Federal Express one to two day delivery

As discussed in the Chapter IV, these common carriers have significant limitations that impact the comparison with LOGAIR. The Federal Express maximum shipment weight is 150 pounds, and the other modes maximum shipment weight is 70 pounds (18). Therefore, for shipment weights exceeding these limitations, the common carriers are not alternative modes to LOGAIR. UPS has significant shipment time limitations. The UPS scheduled two day shipment time for the Wright-Patterson AFB - Langley AFB traffic channel is the only channel that meets TP 1 shipment requirements. The UPS scheduled four day shipment time for the other four traffic channels meets TP 2 shipment time requirements only. Finally, First Class Mail offers no guaranteed shipment time, but is usually less than three days for CONUS deliveries. This just meets TP 1 shipment time requirements. These specific limitations are in addition to the various restrictions on hazardous and classified cargo that make up aproximately 3% of CONUS cargo shipments.

The typical shipment weights for cargo transported on LOGAIR were as follows:

1. 3 pounds (25th percentile)
2. 13 pounds (50th percentile or median)
3. 47 pounds (75th percentile)

Tables 5.4 - 5.8 present the actual LOGAIR costs, LOGAIR Tariffs, and common carrier rates for the three typical shipment weights on the five traffic channels. According to the 2750 ABW Traffic Management Office, United Parcel Service (UPS) is the principal LOGAIR competition for shipments from Wright-Patterson AFB (18). Information in the Tables validates this reasonable strategy. UPS is competitive with all three LOGAIR Rates for all five channels, but shipment schedules limit the competition to air eligible cargo for all zones, and air priority cargo for Zone 4 only. In contrast, Federal Express next morning delivery is not competitive with any LOGAIR Rate on any channel. The remaining common carrier modes are addressed for the individual traffic channels.

For the Langley AFB traffic channel, the only competition other than UPS is First Class Mail with the LOGAIR Rate 3 for heavy shipments. On the Loring AFB traffic channel, none of the other common carriers are competitive with LOGAIR.

First Class Mail is competitive with all LOGAIR Rates on the Kirtland AFB traffic channel, along with Express Mail and Federal Express one to two day delivery for shipments greater than 10 pounds. This degree of competition is due mainly to the LOGAIR indirect routing for the traffic. channel.

For the Nellis AFB and McChord AFB traffic channels, none of the other common carriers are competitive with LOGAIR Rates 1 and 2. Only First Class Mail is competitive with LOGAIR Rate 3 for all shipment weights, while Express Mail and Federal Express one to two day delivery are competitive with LOGAIR Rate 3 for heavy shipments.

In general, the common carrier modes are only competitive with LOGAIR Rate 3, except for Zone 4 traffic handled by surface freight. And since LOGAIR cents per pound costs do not reflect the administrative and handling costs for individual shipments, the common carrier rates become more competitive the heavier the shipment and the longer the distance.

Table 5.4

WPAFB-Langley AFB Shipping Costs in Dollars

Costs and Tariff Rates	3 lb	13 lb	47 lb
LOGAIR Rate 1	.96	4.17	15.07
LOGAIR Rate 2	1.01	4.37	15.79
LOGAIR Rate 3	1.64	7.09	25.64
LOGAIR Tariff	.48	2.08	7.52
United Parcel Service	1.80	3.48	9.19
First Class Mail	3.16	9.12	28.78
Express Mail (next day)	10.70	17.35	42.60
Federal Express (1 to 2 day)	14.50	24.50	57.00
Federal Express (next A.M.)	28.00	52.00	86.00

Table 5.5

WPAFB-Loring AFB Shipping Costs in Dollars

Costs and Tariff Rates	3 lb	13 lb	47 lb
LOGAIR Rate 1	.98	4.25	15.35
LOGAIR Rate 2	1.03	4.45	16.09
LOGAIR Rate 3	1.67	7.23	26.13
LOGAIR Tariff	1.02	4.42	15.98
United Parcel Service	1.95	4.09	11.36
First Class Mail	3.45	10.49	33.71
Express Mail (next day)	10.70	18.55	47.05
Federal Express (1 to 2 day)	14.50	24.50	57.00
Federal Express (next A.M.)	28.00	52.00	86.00

Table 5.6

WPAFB-Kirtland AFB Shipping Costs in Dollars

Costs and Tariff Rates	3.1b	13 lb	47 lb
LOGAIR Rate 1	2.85	12.34	44.62
LOGAIR Rate 2	2.98	12.93	46.76
LOGAIR Rate 3	4.85	21.00	75.92
LOGAIR Tariff	1.38	5.98	21.62
United Parcel Service	2.15	4.93	14.38
First Class Mail	3.74	11.79	38.41
Express Mail (next day)	10.70	19.90	51.95
Federal Express (1 to 2 day)	14.50	24.50	57.00
Federal Express (next A.M.)	28.00	52.00	86.00

Table 5.7

WPAFB-Nellis AFB Shipping Costs in Dollars

Costs and Tariff Rates	3 lb	13 lb	47 lb
LOGAIR Rate 1	2.08	9.01	32.57
LOGAIR Rate 2	2.18	9.44	34.13
LOGAIR Rate 3	3.54	15.33	55.43
LOGAIR Tariff	1.83	7.93	28.67
United Parcel Service	2.36	5.81	17.54
First Class Mail	3.96	13.10	43.16
Express Mail (next day)	10.70	21.15	56.30
Federal Express (1 to 2 day)	14.50	24.50	57.00
Federal Express (next A.M.)	28.00	52.00	86.00

Table 5.8

WPAFB-McChord Shipping Costs in Dollars

Costs and Tariff Rates	3 lb	13 lb	47 lb
LOGAIR Rate 1	1.95	8.45	30.55
LOGAIR Rate 2	2.07	8.99	32.51
LOGAIR Rate 3	3.37	14.60	52.78
LOGAIR Tariff	2.10	9.10	32.90
United Parcel Service	2.57	6.73	20.88
First Class Mail	4.32	14.73	49.03
Express Mail (next day)	10.70	22.85	62.50
Federal Express (1 to 2 day)	14.50	24.50	57.00
Federal Express (next A.M.)	28.00	52.00	86.00

VI. Conclusions and Recommendations

In keeping with the organization of the thesis, the conclusions and recommendations will be presented in separate sections, each corresponding to a separate chapter.

Data Evaluation

Data Reliability. The collection of CONUS cargo shipment data by HQ AFLC was a considerable undertaking. HQ AFLC/DST faced a problem of numerous data sources with different shipment documentation methods. Consequently, the complexity of the data collection effort led to questions regarding the reliability of the empirical data base. The shipment data received by HQ AFLC/DST was properly formatted for input to the empirical data base, but logic problems were noted and addressed in the analysis section. The reliability question mainly concerned the completeness of the data collection effort. Assuming that T-WRAPS provides an accurate measure of the number of CONUS shipments from Air Force installations (not including shipments from the ALCs or reported by TIPS), then HQ AFLC/DST received information on approximately one-half the actual number of shipments, with wide variations between the Air Force installations.

Data Validity. The data collected adequately incorporated the parameters necessary for accurately describing what was shipped within the USAF CONUS distribution network. Two variables could be included which would improve the utility of the data base.

First, the hazardous material field should have specific coding which delineates any restrictions on the mode of transportation. Since hazardous material is only 2% of all shipments, this detail required may not be worth the effort. An easier alternative may be building a restriction into a final model which prohibits all hazardous material from being transported by commercial common carrier. This assumption would only be used to simplify the modeling effort. Some hazardous material could be moved by common carrier when the proper regulations are followed.

The second variable that could be included is the distance from origin to final destination, especially for TP 1 cargo. Some TP 1 could be allocated to less-than-truckload carriers if the total distance to be shipped were less than 900 miles. However, without knowing the shipping distance, the model could not determine which shipments would qualify.

Data Practicality. The data collection effort for this study required a tremendous expenditure of time and manpower by HQ AFLC/DST and the data sources. Original estimates based on receipt of approximately three million shipment records were $425,000.00 for the manual data collection and transcription, not including reprogramming costs for D009, weight is an accurate predictor of volume. Therefore, a model could incorporate cost as a function of weight and not have the results degraded by an inordinate number of light, bulky shipments.

Analysis of Cost Behavior

Cost Behavior with Distance Fixed. Any model developed cannot assume that the cost of a shipment between fixed origins and destinations is a fixed price per pound regardless of weight. Two common carrier modes, Express Mail and First Class Mail, are almost priced at a constant price per pound. However, Surface Parcel Post, Federal Express, United Parcel Service, and less-than-truckload rates are non-linear for fixed origins and destinations. If a model were to assume linearity for those four common carrier modes, an error would be built into the final result.

Cost Behavior with Distance Not Fixed. Common carrier pricing structures are not independent of distance. That is, a model could not assume a fixed rate, expressed in dollars per pound, regardless of the distance to be shipped. For shipments under 20 pounds, the rates of the common carrier modes are often identical, when destinations in two adjacent zones are compared. For shipments over twenty pounds, the rates are less for the shorter hauls. As a result of these findings, an error would be induced into a final model if cost were considered to be independent of distance.

Implications of Data Analysis and Cost Behavior

The majority of Air Force CONUS shipments are less than 20 pounds (60%). Most common carriers have a decreasing rate expressed in price per pound up through about 20 pounds. Therefore, assuming linearity of cost would induce an error into about 60% of all shipments. However, all common carriers had a relatively linear price structure if only weights 1-20 pounds were considered. At a minimum, any model developed should concentrate on expressing the 1-20 pound rate as accurately as possible.

Cost Comparison

Computations for the true costs of LOGAIR should take into consideration the actual transportation requirements of the cargo moved via LOGAIR. LOGAIR costs based on total cargo moved provides the transportation manager with decision criteria for transportation problems.

The LOGAIR Tariffs closely approximated costs based on total cargo for traffic channels served by direct routing, but LOGAIR Tariffs do not recoup the actual shipment costs for total cargo moving via indirect routing. LOGAIR Tariffs do not come close to covering LOGAIR costs based, on high priority cargo only, for any of the traffic channels analyzed.

In general, the common carrier tariff rates are competitive with LOGAIR only when LOGAIR costs are based on the actual high priority cargo moved. The single exception is when surface transportation provided by common carriers can

0013, and TIPS data bases or HQ AFLC/DST manpower costs. HQ AFLC/DST's best efforts to establish the empirical data base were limited by the multitude of methods used to document and report shipments in the CONUS. In addition, the requirement to collect past shipment data, rather than establishing a data collection plan and then starting the collection, definately increased the problem. HQ AFLC/DST still received shipment records five months after the end of the data collection period.

DOD should standardize shipment documentation and reporting procedures for all DOD traffic managers. An empirical data base of all CONUS shipments could then be simply designed and maintained for any future analysis of the Defense Transportation System. This is extremely important if the USAF transportation community wants to improve its understanding of CONUS cargo movement requirements. Modeling of the transportation system absolutely requires accurate forecasts of these requirements. With a sufficient number of historical data points, time series and other objective forecasting techniques could be applied. Without an historical data base, "educated guessing" is the only alternative forecasting technique.

Analysis of CONUS Freight Shipments

The general conclusion from analyzing the data base is that within the CONUS single, small shipments dominate. Half of all shipments are 12.02 pounds or less and are 1.79

Transportation Priority 1 (TP 1) cargo. MICAP consists of generally lighter shipments, and has a median weight of 6.72 pounds.

-Commensurate with the findings of small weights and small sizes was the finding that 97% of all CONUS shipments are a single piece, and 99% are 5 pieces or less. The system handles a large number of unconsolidated shipments. Whether the system should attempt more consolidation would require taking a closer look at individual channels and the delivery standards for cargo in those channels.

The CONUS transportation network is supporting the distribution of critical aircraft parts and engines, the largest single classification of type of shipment. These parts and engines comprised 43.6% of all shipments made within the CONUS by all modes. Many of these parts are high priority, as 44% of all shipments are TP 1, which have at most a three day delivery requirement. However, of the TP 1 26.8% are MICAP, which means that the part must be shipped by the most expeditious means and does not have the "luxury" of the three day delivery. Of the shipments included in the HQ AFLC survery, 11.7% are designated as MICAP priority. As stated previously, the characteristics of MICAP reveal generally lighter shipments, as the median weight is 6.72 pounds, where as all CONUS shipments and all TP 1 shipments have a median of over 12 pounds.

In viewing the relationship between weight and volume, substitute for LOGAIR and still meet UMMIPS standards. Air common carrier rates become more competitive the heavier the shipment and the longer the distance.

Developing a Computer-Based Transportation Model

The second phase of the CONUS Cargo Movement Study Plan suggested the need for a computer-based model of the Air Force CONUS transportation system. The background information in Chapter I indicated that optimization models are useful for only certain levels of decision-making. Thus the first step is determining the decision requirement. Without questions, there are no answers, and without objectives or goals, no worthwhile alternatives for decision making can be developed. Until senior transportation managers can identify the decisions they want supported, the only possible modeling alternative is a simulation model. Even a simulation model will not answer the question of how much to spend on wartime capability and readiness during peacetime. That strategic planning decision is qualitative and beyond this type of modeling.

The decision on the desired level of LOGAIR service must be made before developing a model to minimize the costs of the remaining transportation requirement. Once funds are allocated for this LOGAIR service, then readily available routing and scheduling models can determine an effective LOGAIR system. An approach for modeling the entire transportation system would assume a capacitated network design for the dedicated contract service (LOGAIR), and an uncapacitated network design for common carrier service to meet the remaining transportation requirement, based on the "unlimited" capability of nondedicated common carrier service. The model must maximize the cargo movement on dedicated contract service, the protocol based on first moving the cargo that requires this service. with the remaining capacity used for the movement of opportune cargo, based on next highest priority. This assumes dedicated contract service costs are independent of cargo movement for a given service level (the present contracting arrangment). The remaining cargo requirements would be moved on the uncapacitated network design representative of common carrier service, with the objective function of minimizing costs. The two network designs must treat each traffic channel independently for cargo movement requirements and shipment mode selection, with only feasible modes included as part of the network design. The true costs of the dedicated contract service could be evaluated by simulation of different levels of dedicated contract service and observing the relative impact on total transportation costs. Finally, the model could be run based on daily, weekly, monthly, or seasonal cargo movement requirements to evaluate the effects of cargo movement requirements variation on total transportation costs.

Appendix: Least Squares Equations by Mode

MODE	RANGE OF WEIGHTS	REEXPRESSION	LEAST SQUARES EQUATION
FIRST CLASS MAIL (4)	1-70	N	57.88X + 157.32
USPS SURF(4)	1-70	N	7.78X + 265.56
USPS SURF(4)	2-20	N	16.36X + 152.60
USPS SURF(4)	21-70	N	5.73X + 367.62
USPS SURF(4)	1-70	COST=COST**2	7859.9X + 40,807
USPS SURF(4)	2-20	COST=COST**2	10554.0X + 2895.2
USPS SURF(4)	21-70	COST=COST**2	7123.9X + 77,675
FED EXPRESS	1-100	N	0.68X + 2234.0
FED EXPRESS	2-10	N	237.33X + 847.11
FED EXPRESS	11-100	N	64.02X + 2496.1
UPS (4)	1-70	N	14.22X + 183.52
UPS (4)	1-50	N	16.80X + 129.38
UPS (4)	51-70	N	4.34X + 752.54
EXP MAIL 1 (4)	1-70	N	63.21X + 846.36
LTL(SAC-BOS)	1-10,000	N	.13X + 62.84
LTL(SAC-BOS)	1- 5,000	N	.14X + 37.34
LTL(SAC-BOS)	5000-10,000	N	.13X + 0

(4) IS TO ZONE 4
SAC-BOS IS SACRAMENT TO BOSTON
COST**2 IS COST SQUARED

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This analysis provides a foundation upon which to build a model of the Air Force CONUS freight shipment network. The general findings were that a model is possible; attention must be given to data collected for input to the model; some simplifying assumptions about shipping cost could induce significant error into a model; and LOGAIR costs compete favorably with common carrier charges for similar service.

The study pointed out deficiencies in the data base collected by HQ AFLC related to accuracy and completeness of the shipment records, although the shipment description categories were adequate. The data base was used to determine the specific frequency distributions for weight, volume, number of pieces in a shipment, and priority for three separate populations: all shipments, Transportation Priority 1 shipments, and Mission Capable (MICAP) shipments.

The study analyzed cost behavior, specifically noting that costs expressed in dollars per pound should not be assumed as linear and that costs should not be assumed as independent of the distance shipped. The study also determined LOGAIR shipment costs in cents per pound based on all LOGAIR cargo moved, actual air eligible cargo moved, and actual air priority cargo moved. Compared with common carrier rates, LOGAIR shipment costs based on all LOGAIR cargo moved were cost competitive for similar service.

Finally, the study considers the decision requirements of transportation management for developing an effective and efficient transportation system, and an approach for modeling the transportation system.

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